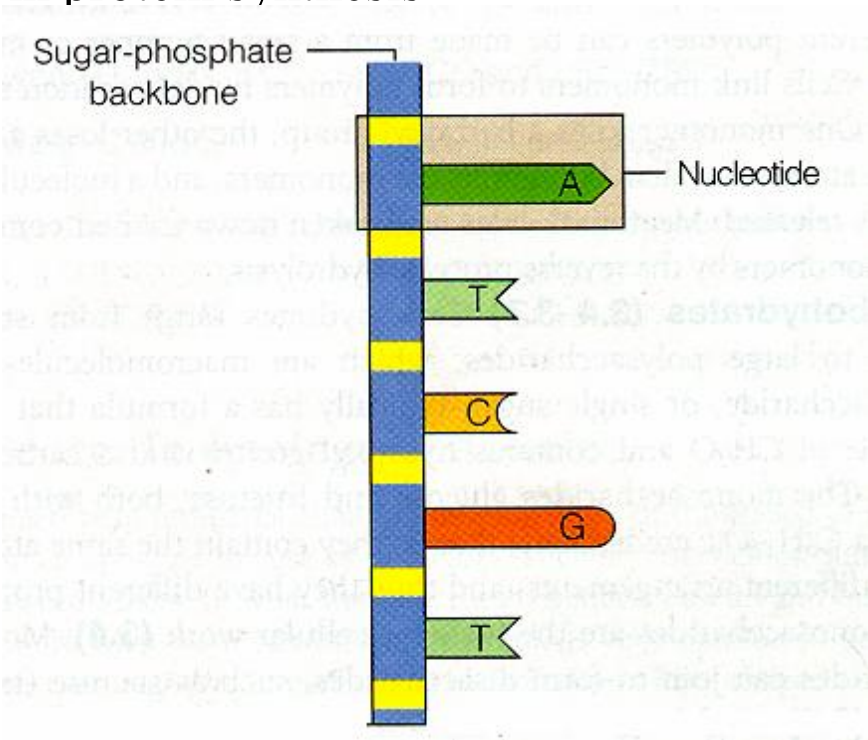
DNA & Cell Division

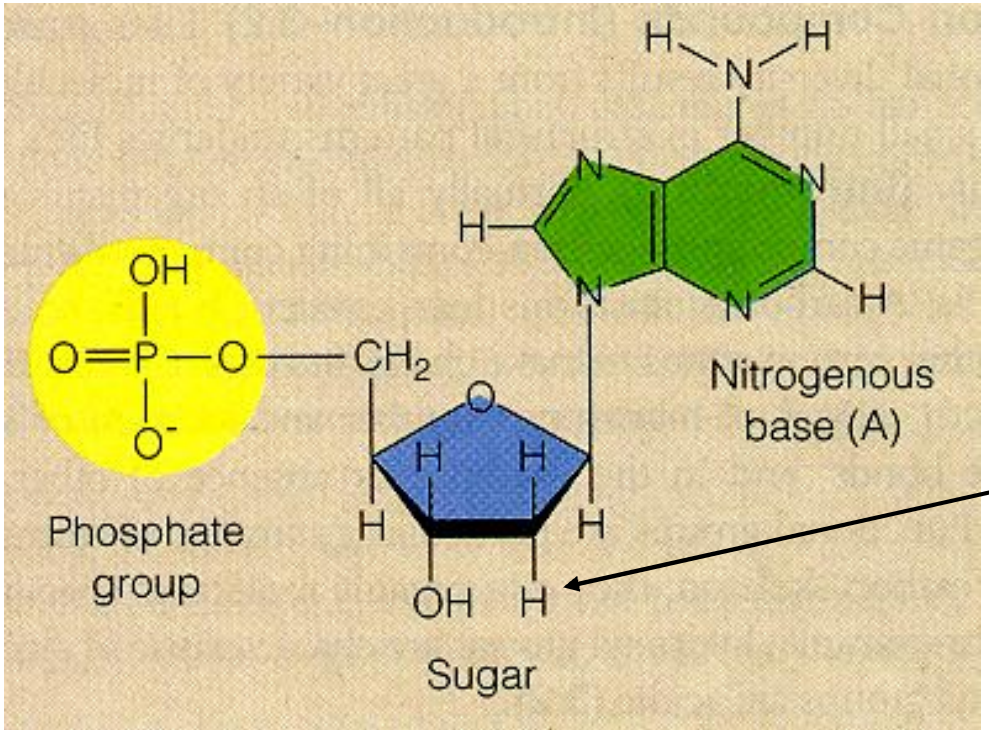
Nucleic Acids

- Polymers of monomers called nucleotides
- serves as blueprint for protein synthesis
- two types of nucleic acids
  - DNA (deoxyribonucleic acid)
    - contains all the inheritable genetic information (genes)
  - RNA (ribonucleic acid)- involved in protein synthesis
    - mRNA
    - rRNA
    - tRNA

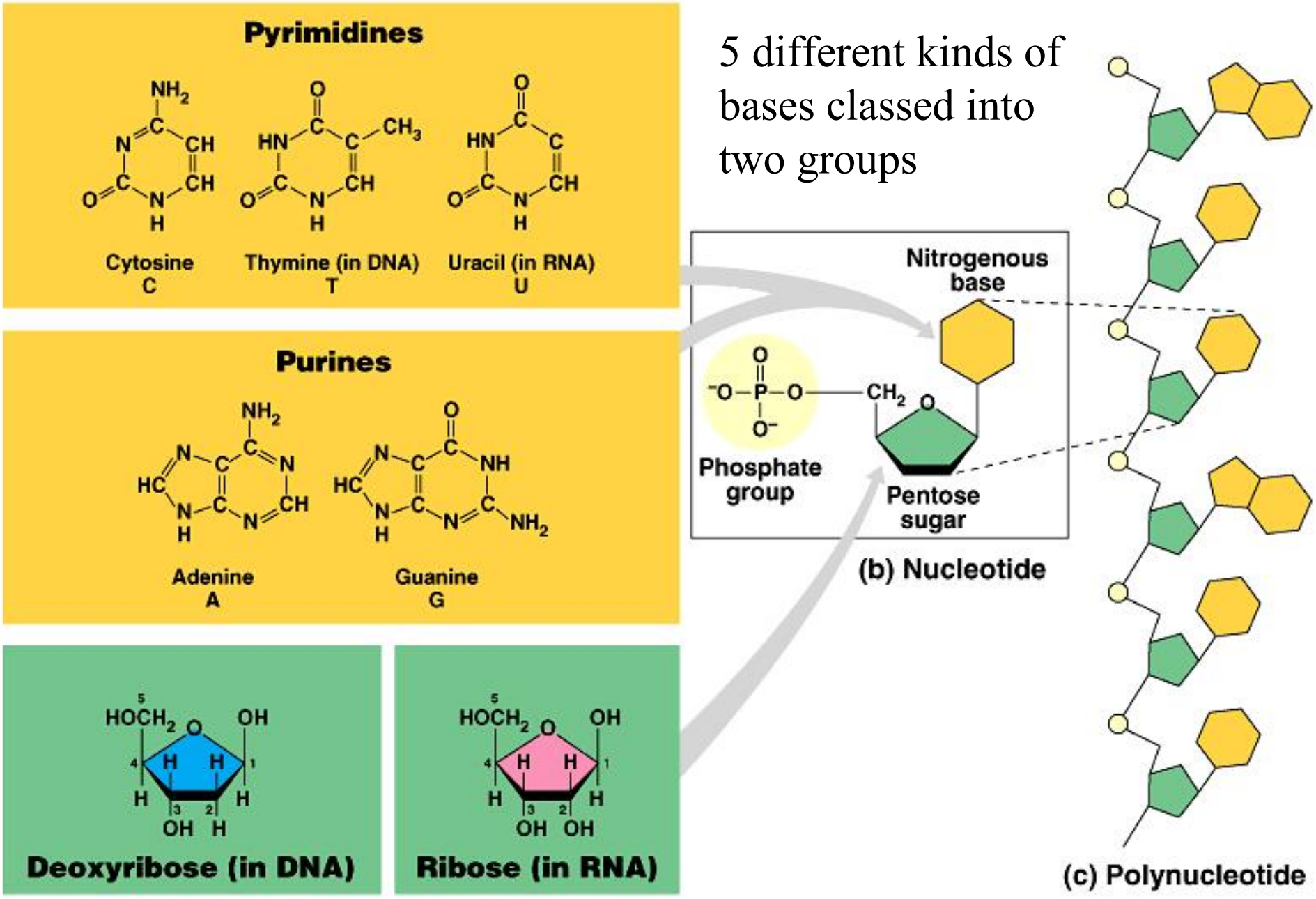


Nucleotide

- Each nucleotide has three parts
  - sugar- ribose (5C sugar) or deoxyribose
  - phosphate group- constant
  - nitrogenous base- variable



5 different kinds of bases classed into two groups



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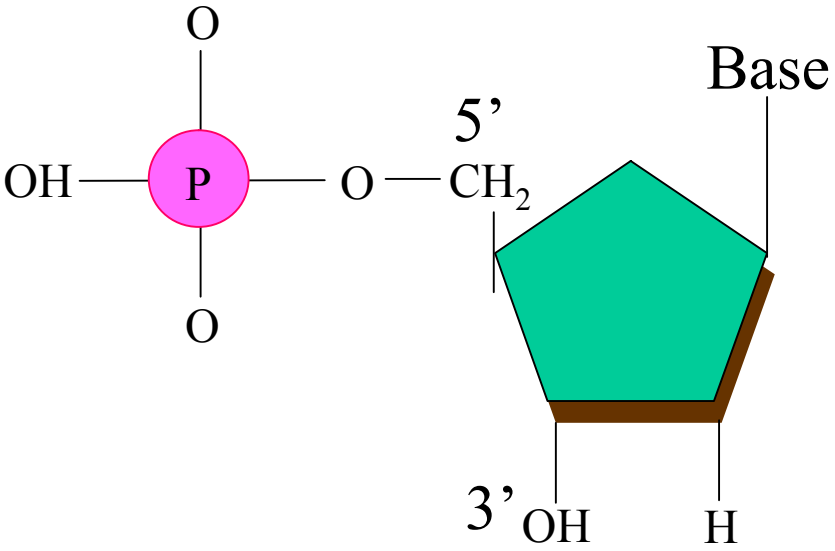
DNA and RNA are Different

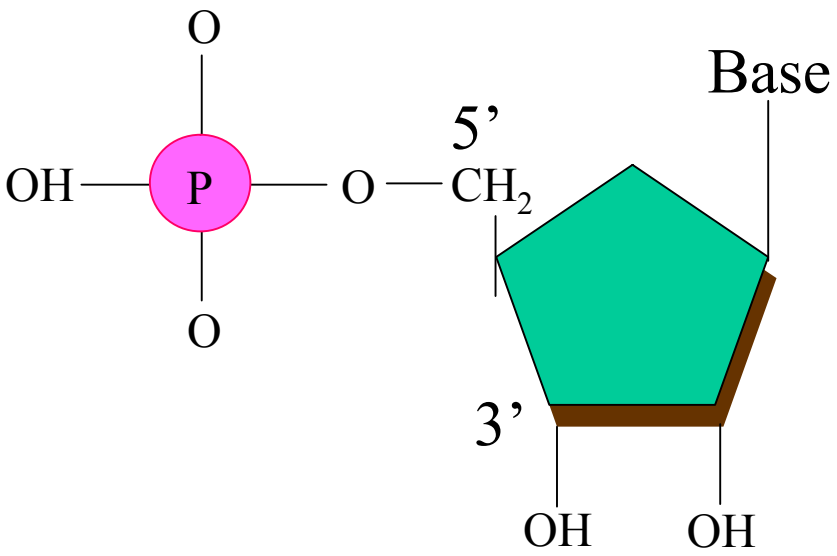
DNA



A,C,G,T

Double Stranded
Long

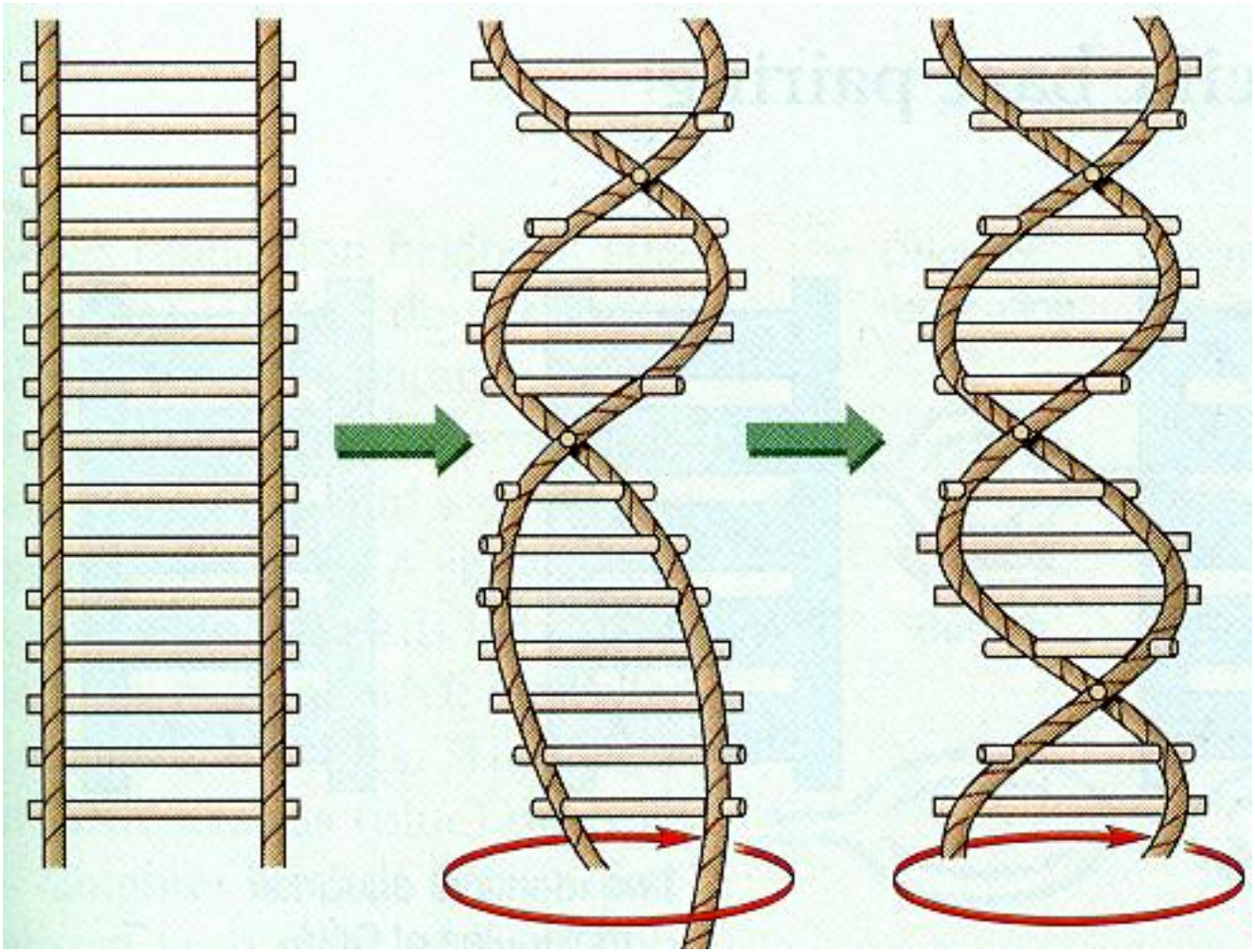
RNA



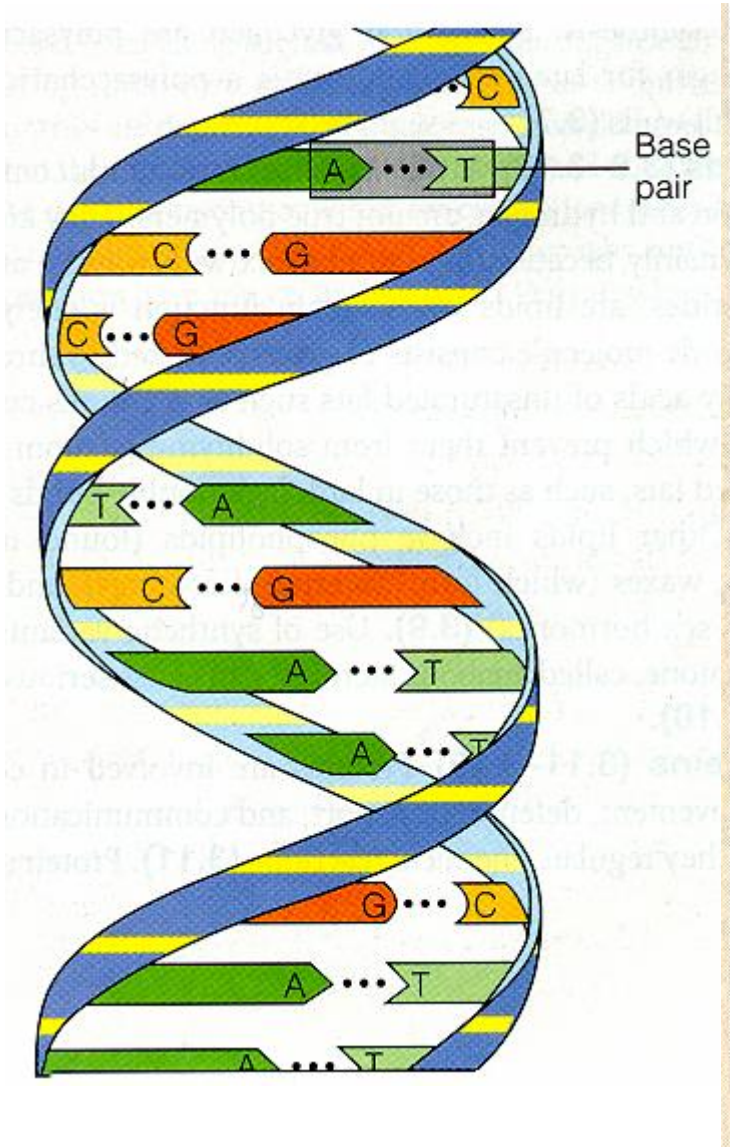
A,C,G,U

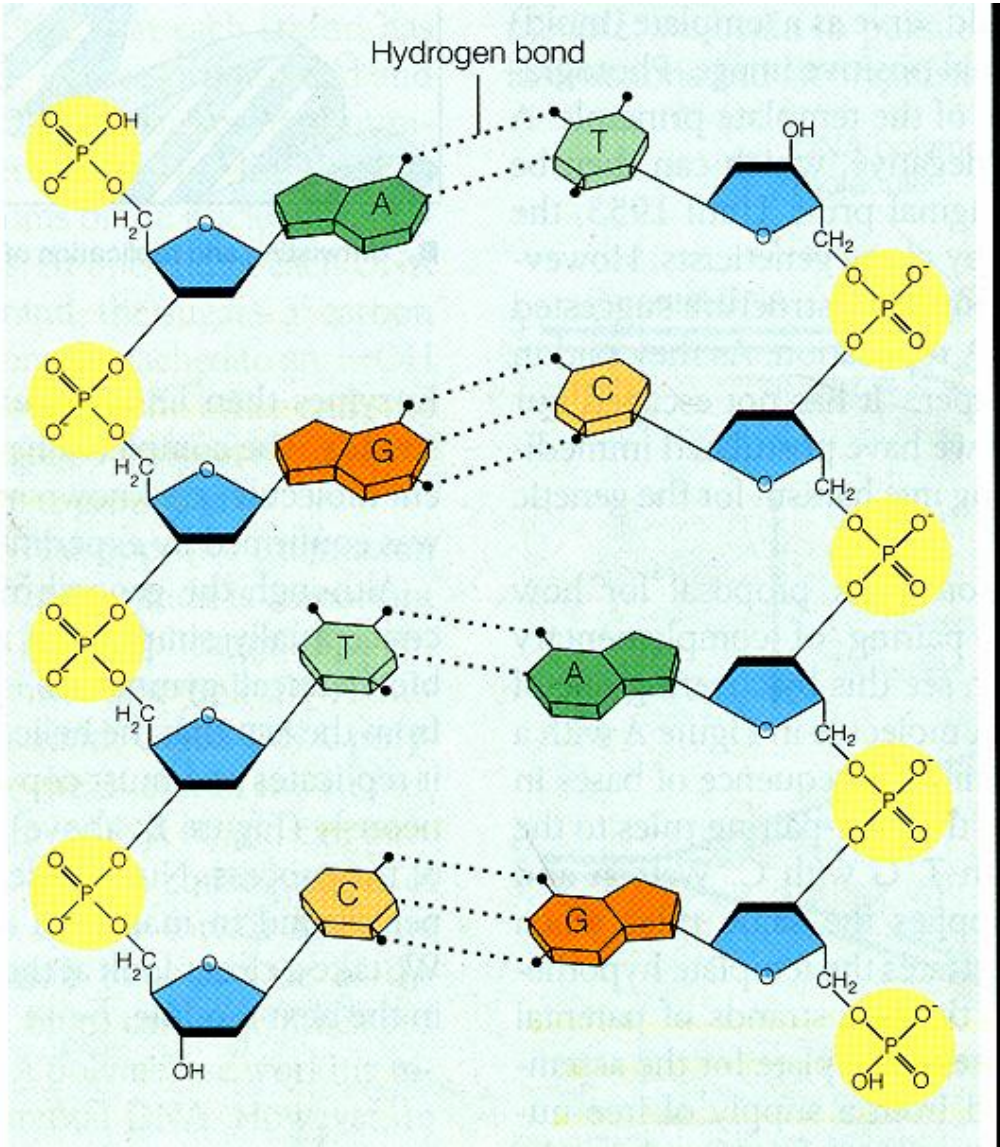
Single Stranded
Short

Double Stranded DNA

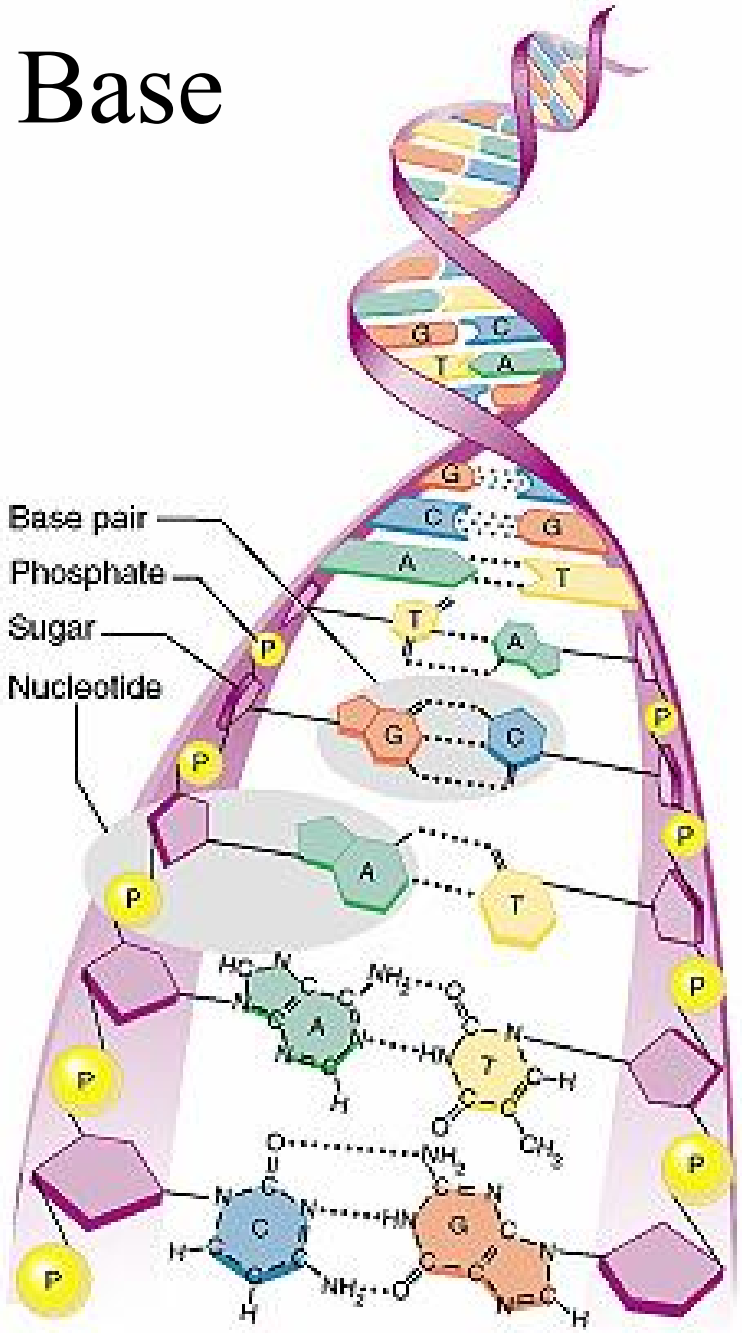


DNA Strand With Complimentary Base Paring





Complimentary Base Pairing



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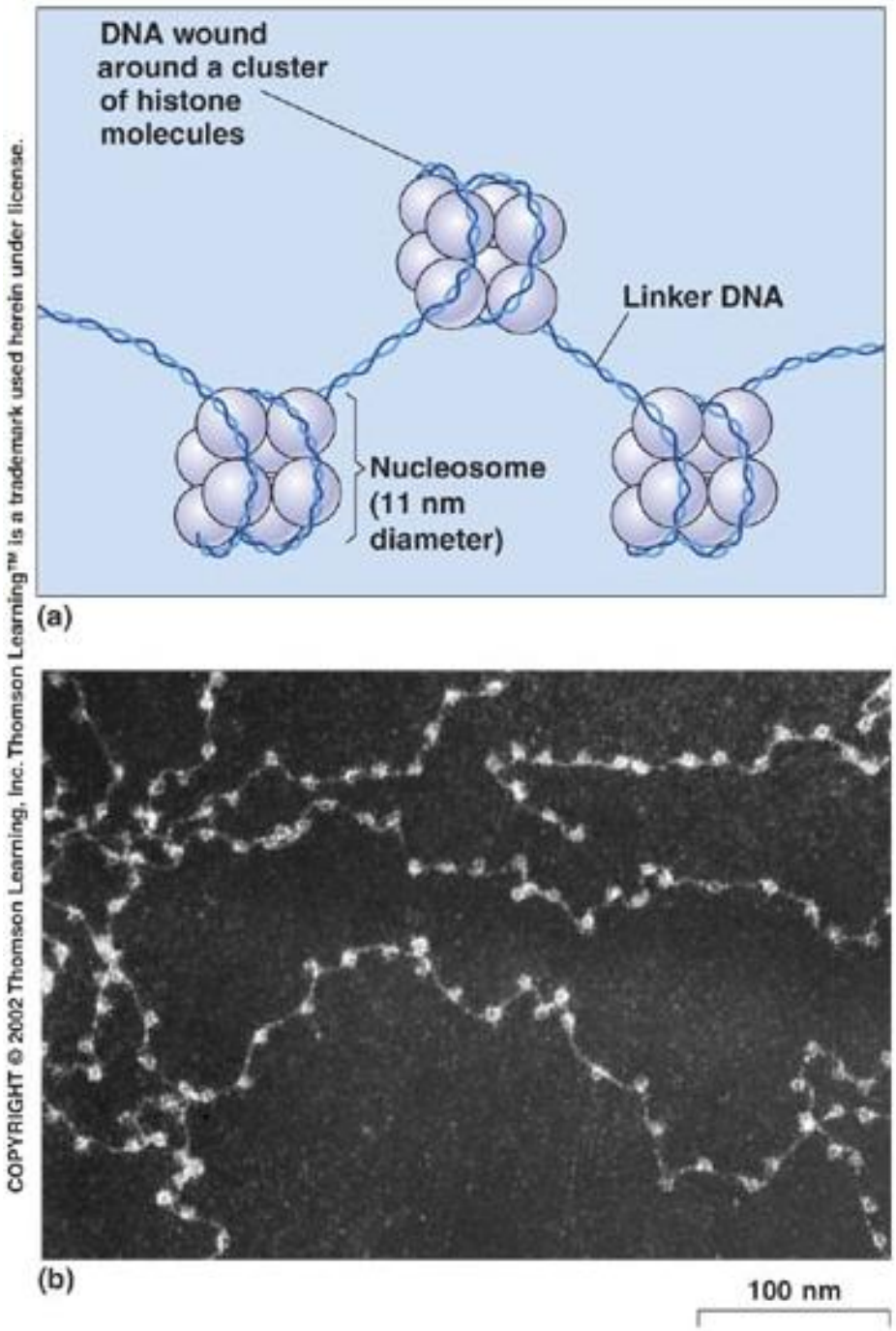
Organization of Genetic Material

- DNA in the cell is thick and very long when compared to the size of the nucleus
  - Perspective: if a DNA molecule was the thickness of a telephone pole, it would reach 2700 miles into space
- The cell has 46 DNA molecules that must fit into the nucleus organized and intact.

Organization of Genetic Material

- **Chromatin**- longs strands of DNA in beaded like strands
- **Nucleosome**- DNA wrapped around a cluster of proteins called histones
- **Non-histons protein-** provide structural support for the chromatin and help regulate gene activity


DNA wound around a cluster of histone molecules
Linker DNA
Nucleosome (11 nm diameter)
(a)
(b)
100 nm
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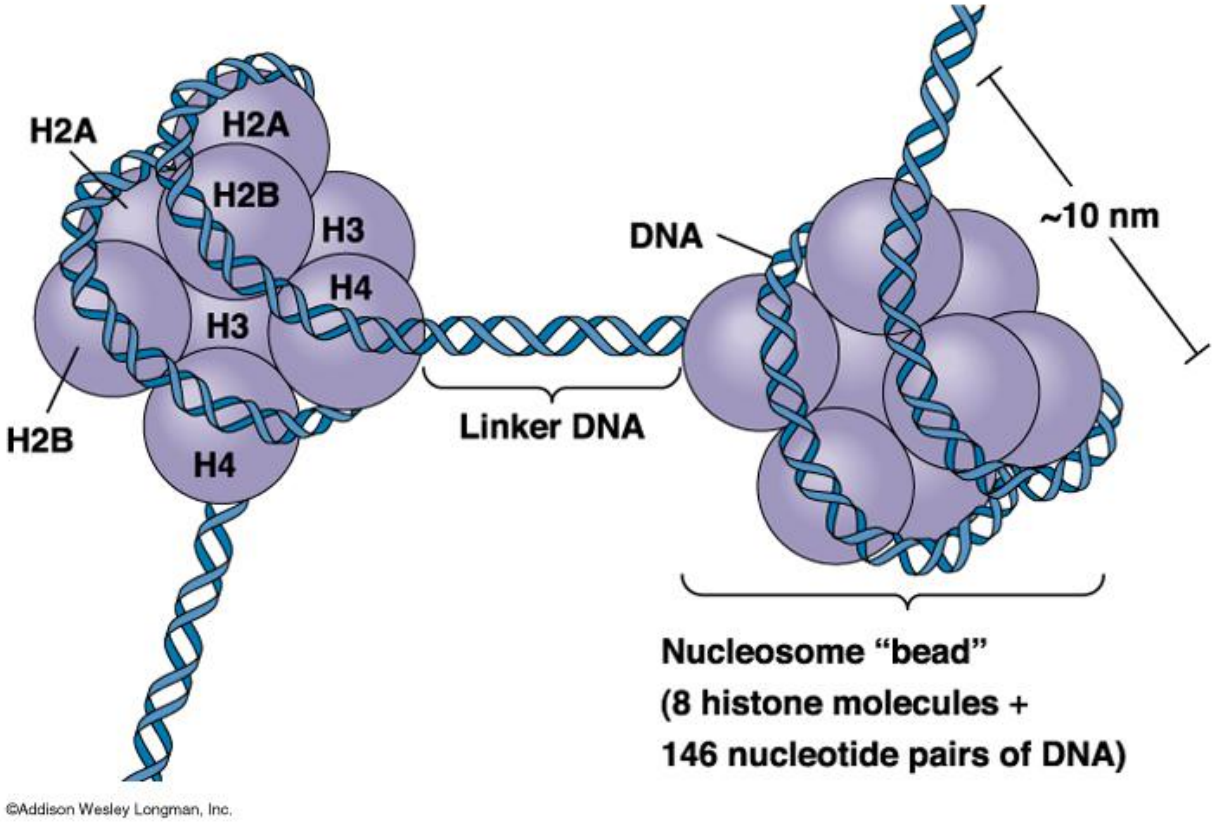
Nucleosome


H2A
H2A
H2B
H3
H4
H3
H2B
H4
DNA
~10 nm
Linker DNA
Nucleosome "bead"
(8 histone molecules +
146 nucleotide pairs of DNA)
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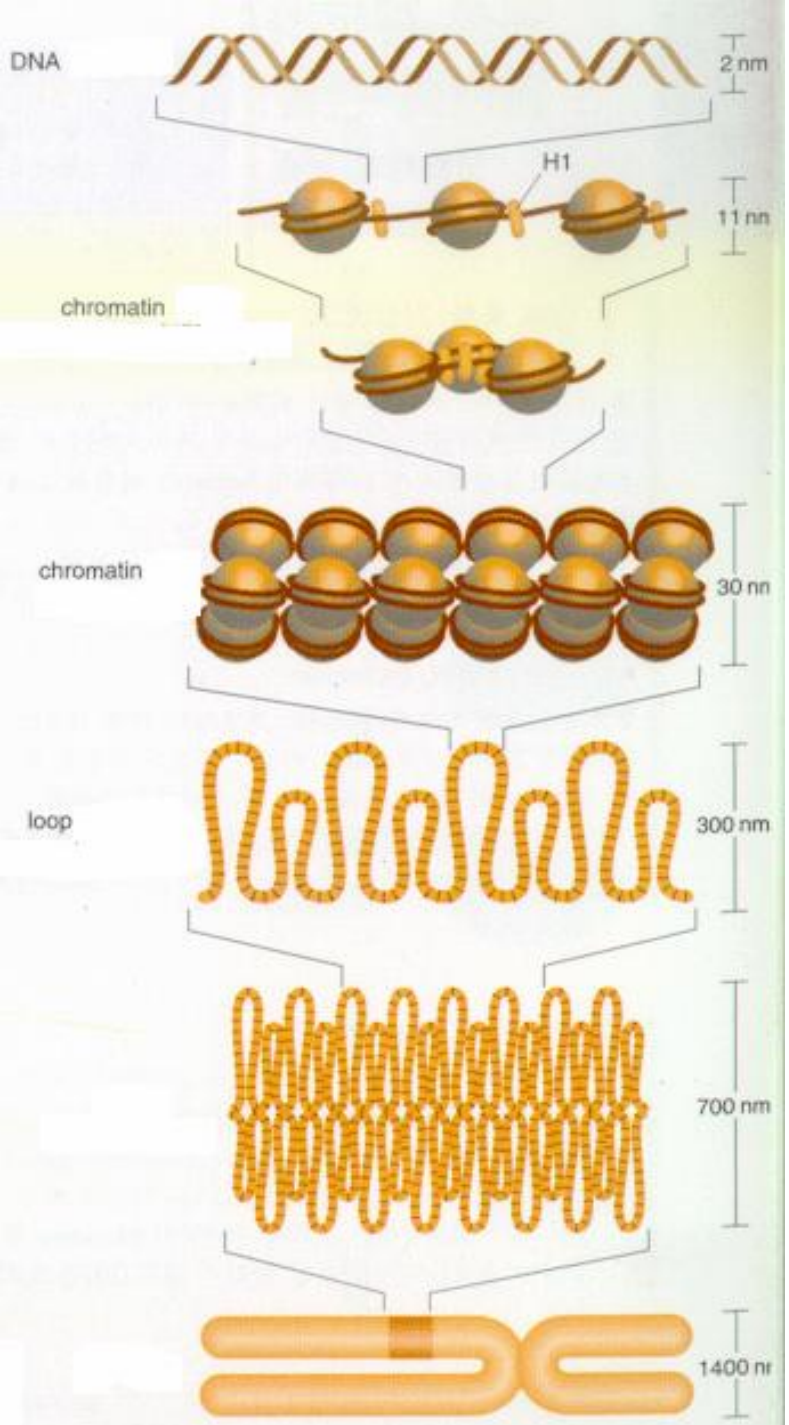

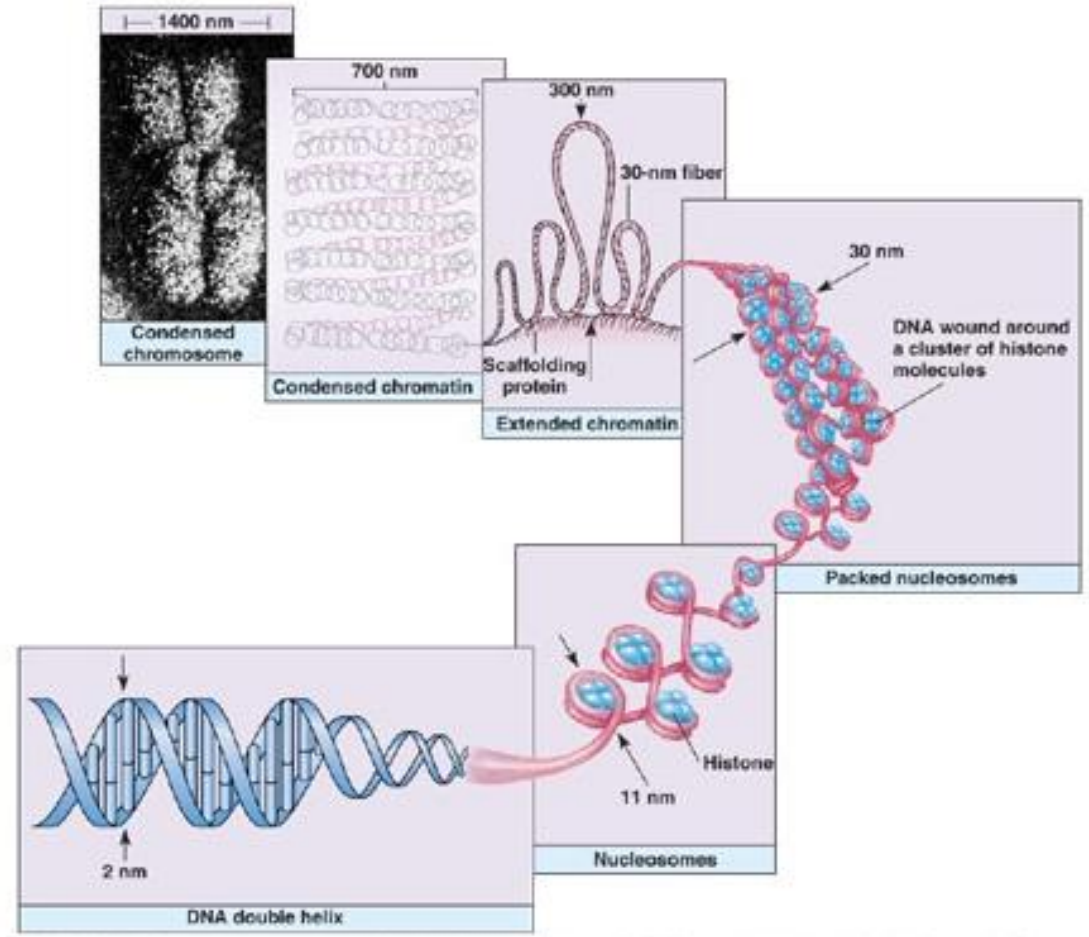

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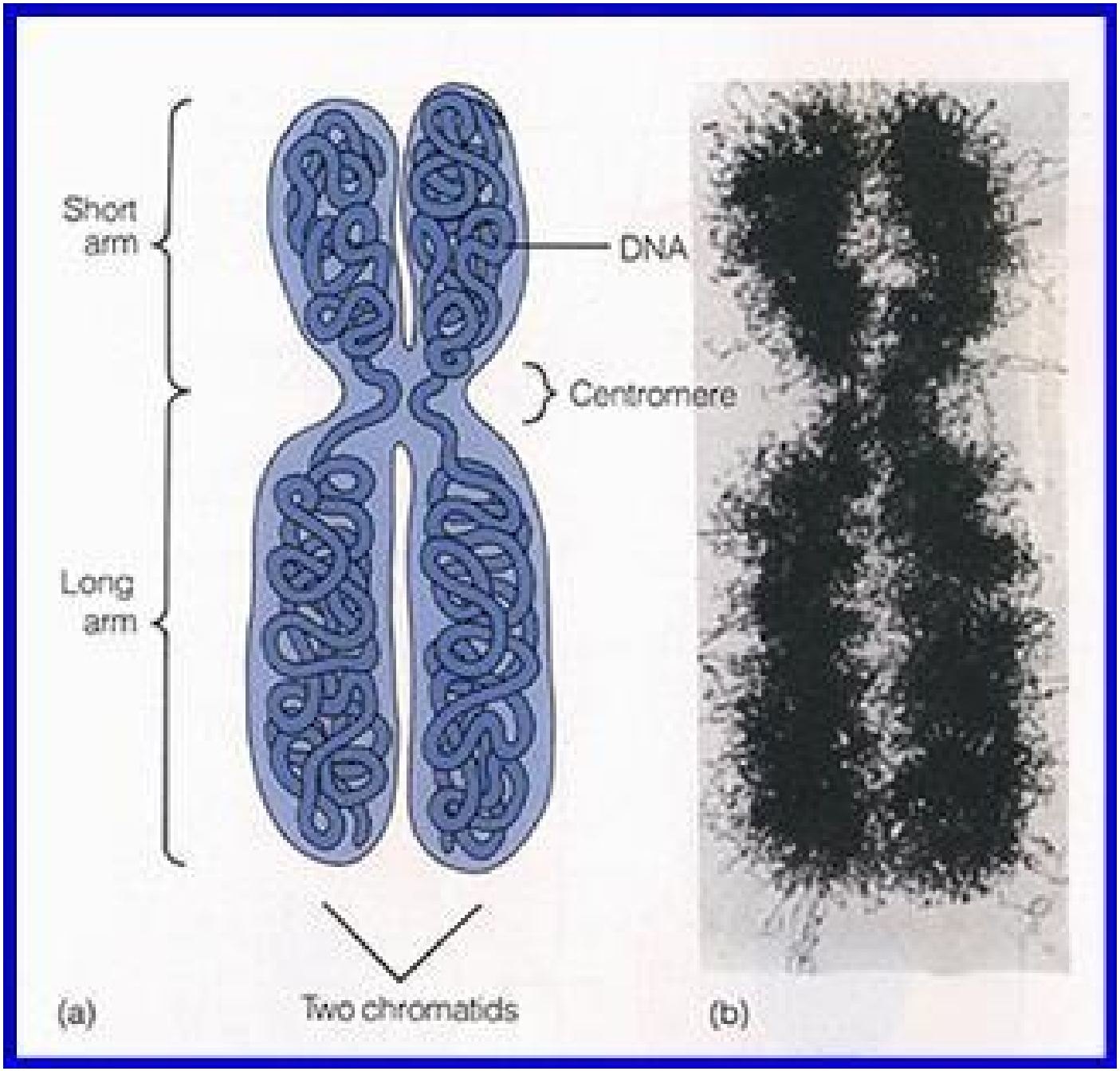

Short arm
Long arm
DNA
Centromere
Two chromatids
(a)
(b)

DNA Replication In Cell Division

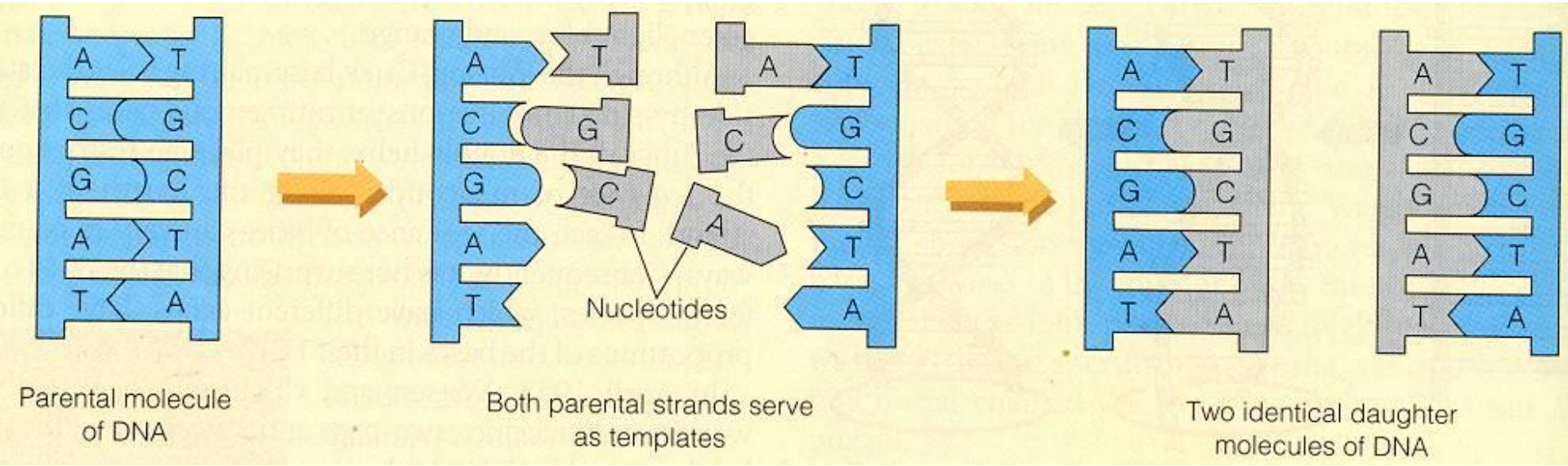
The reasons for cell division

- growth
- repair
- reproduction

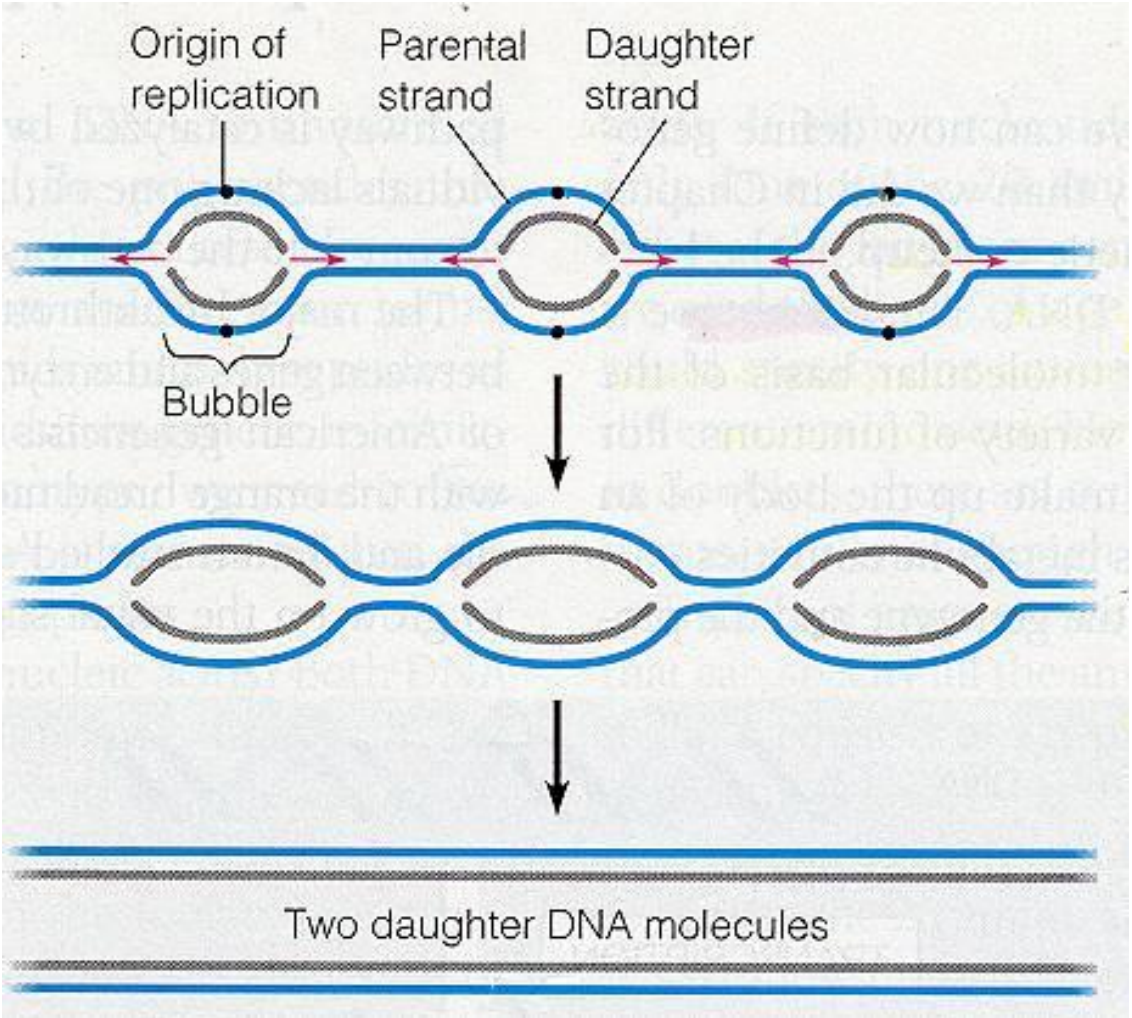
Two kinds of cell division

- somatic cell division- mitosis
- sex cell division- meiosis

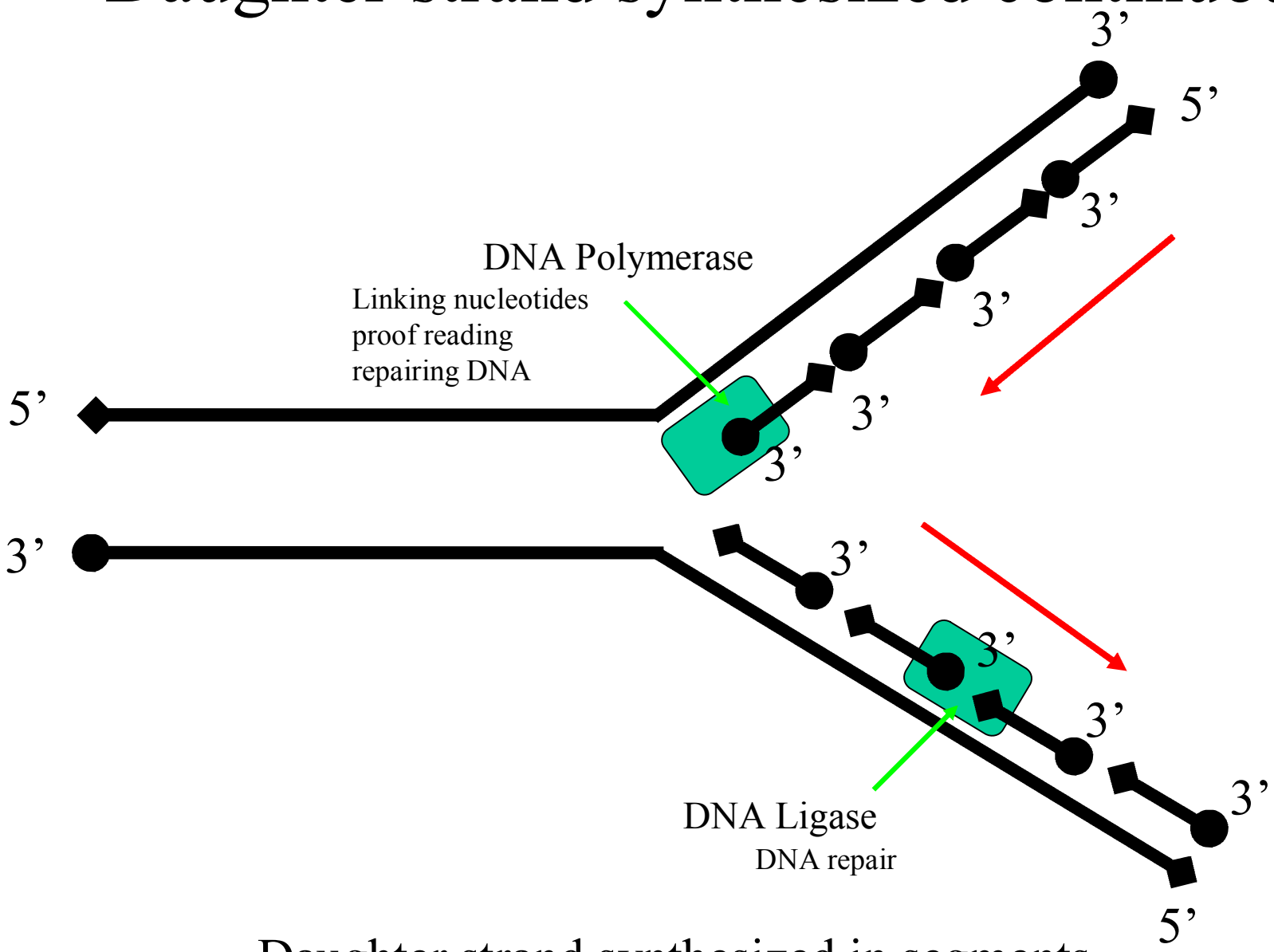
DNA Replication



Replication begins at a Specific Sight on the Double Helix

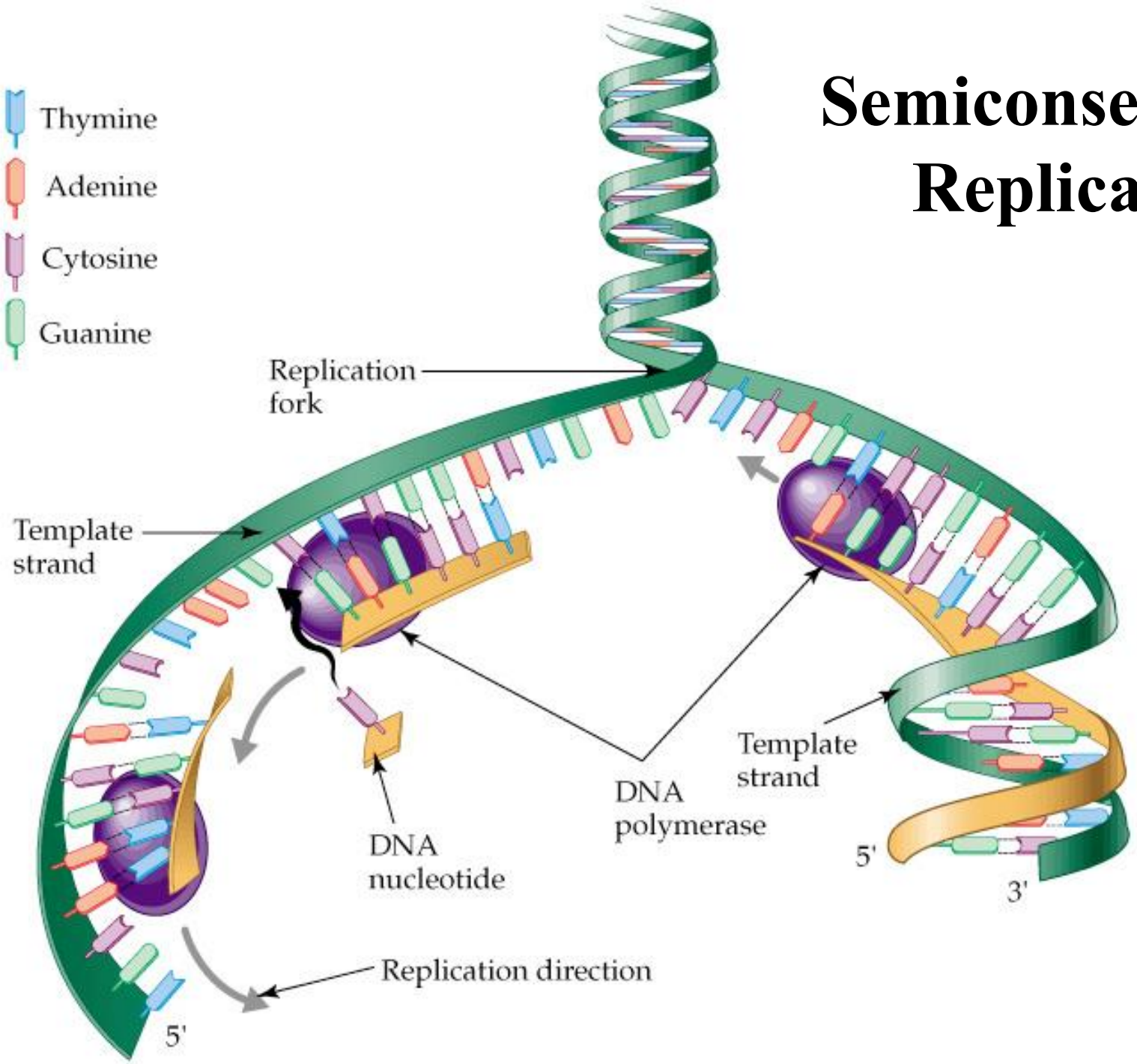


Daughter strand synthesized continuously

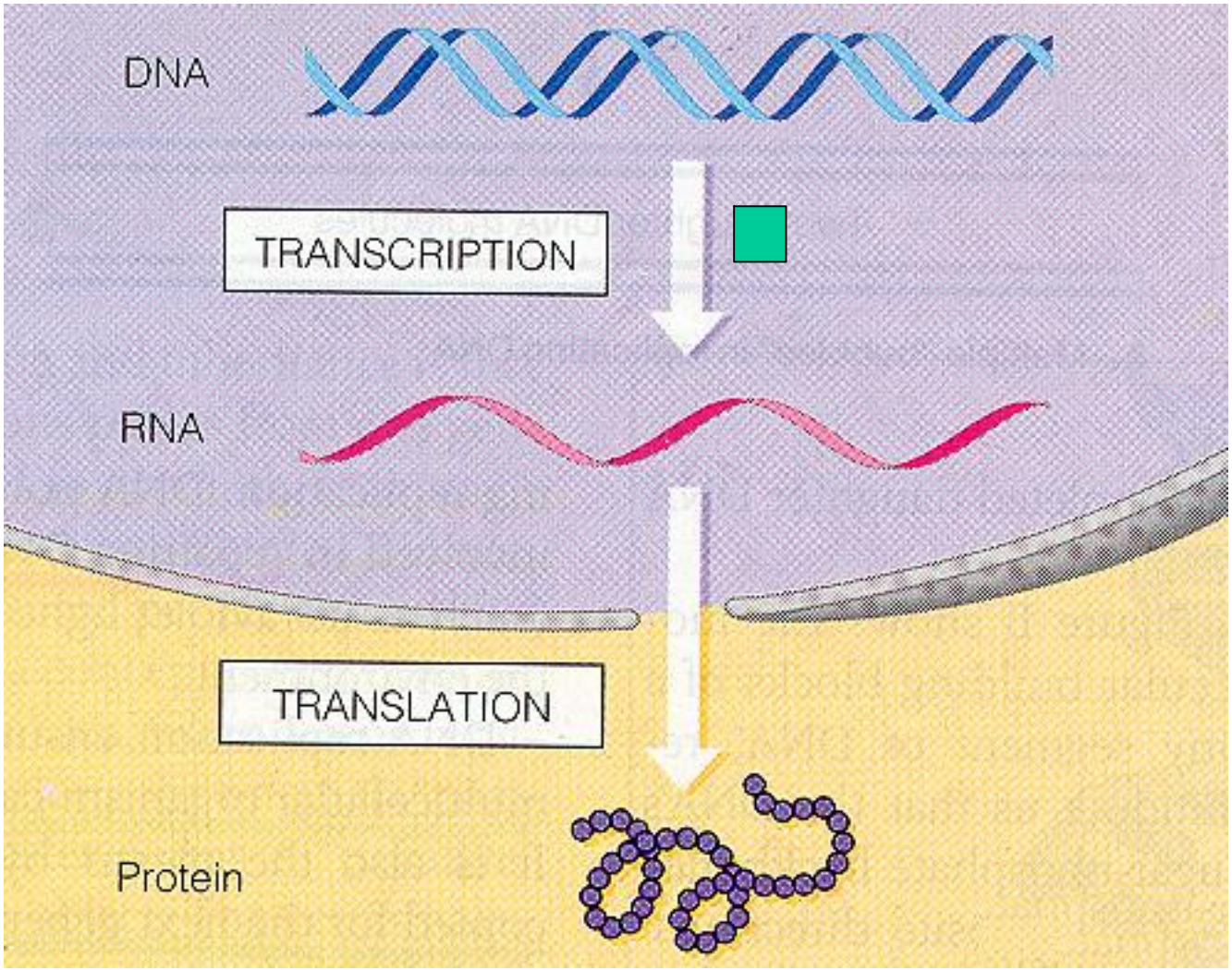


Daughter strand synthesized in segments

Semiconservative Replication

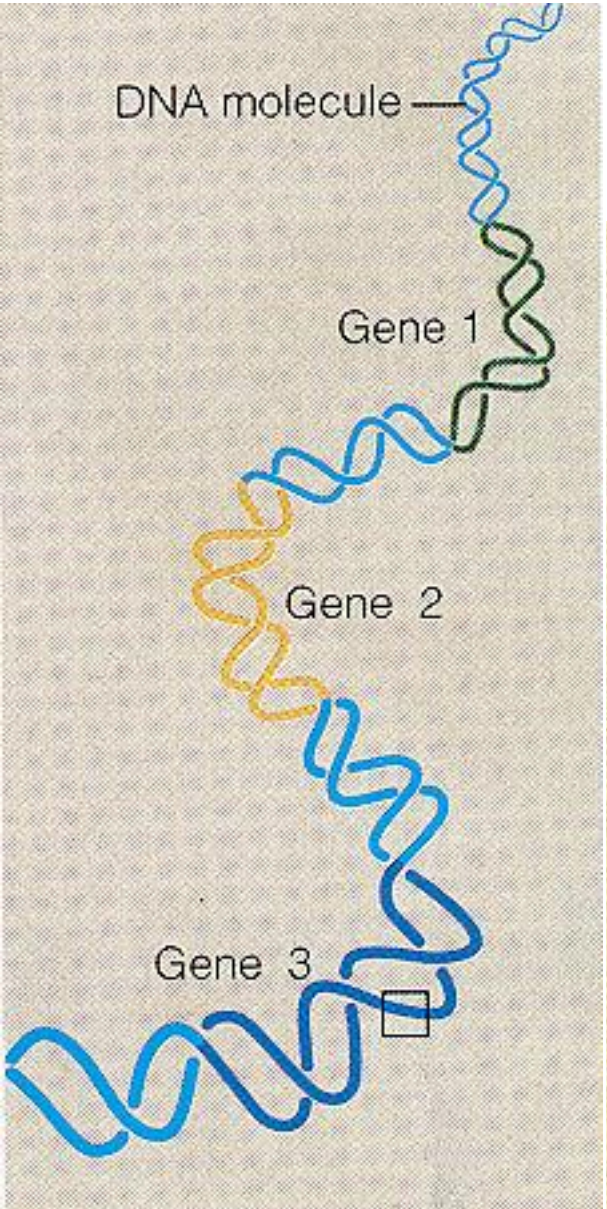


The DNA Genotype is Expressed as Proteins, Which Provide the Molecular Basis for Phenotypic Traits

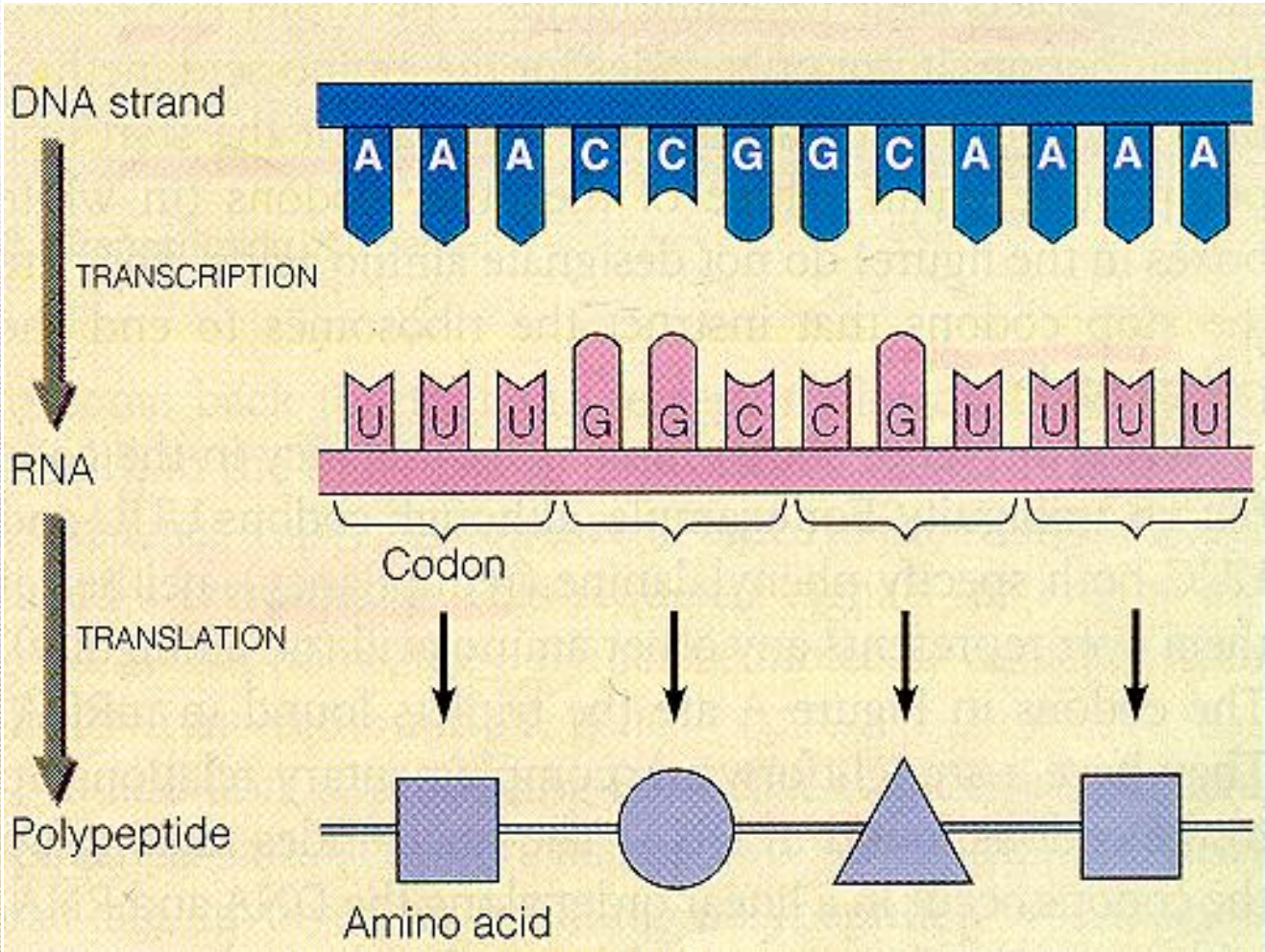


One Gene One Enzyme Hypothesis

Genetic Information is Written as Codons and Translated into Amino Acid Sequences



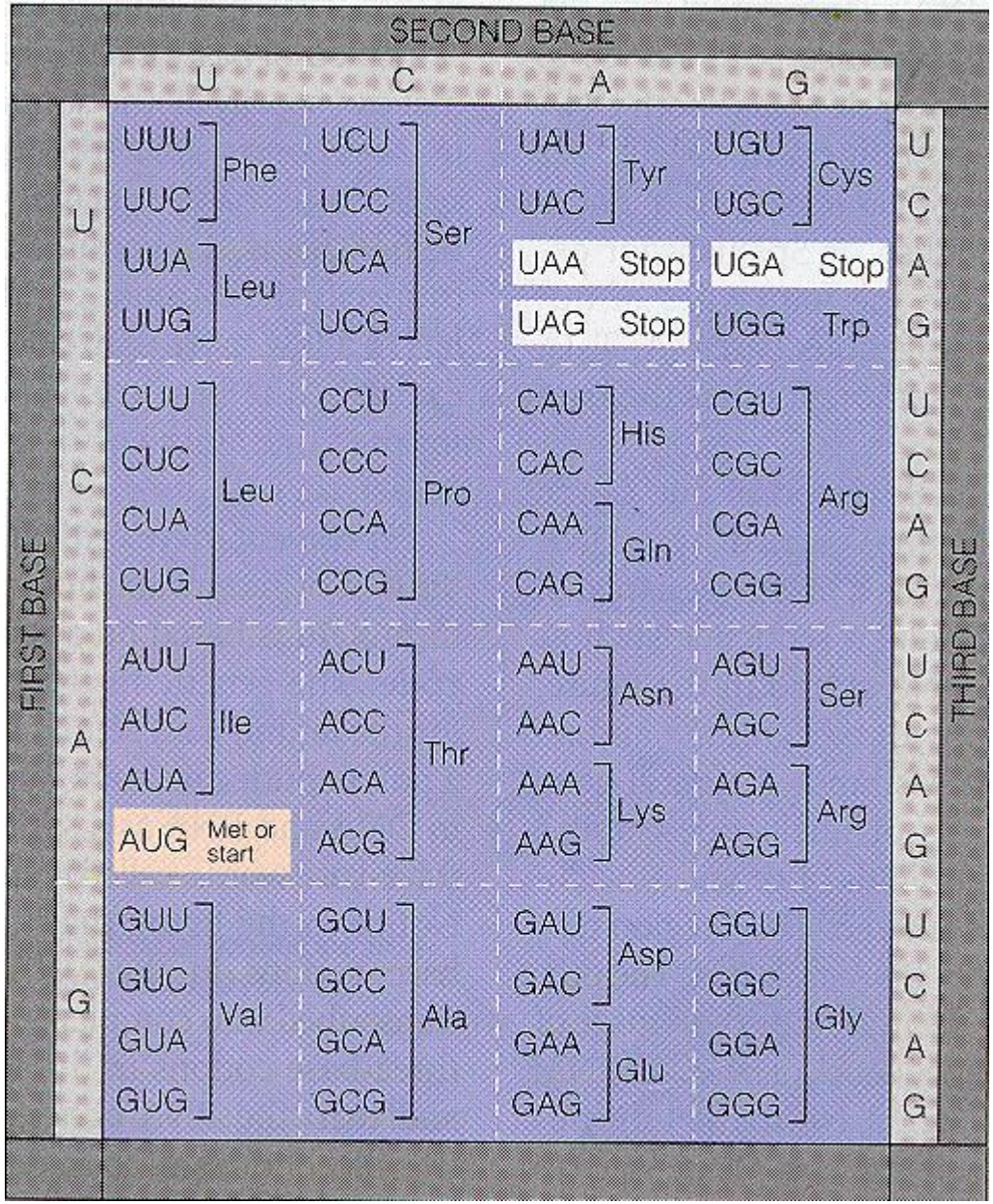
Triplet Code



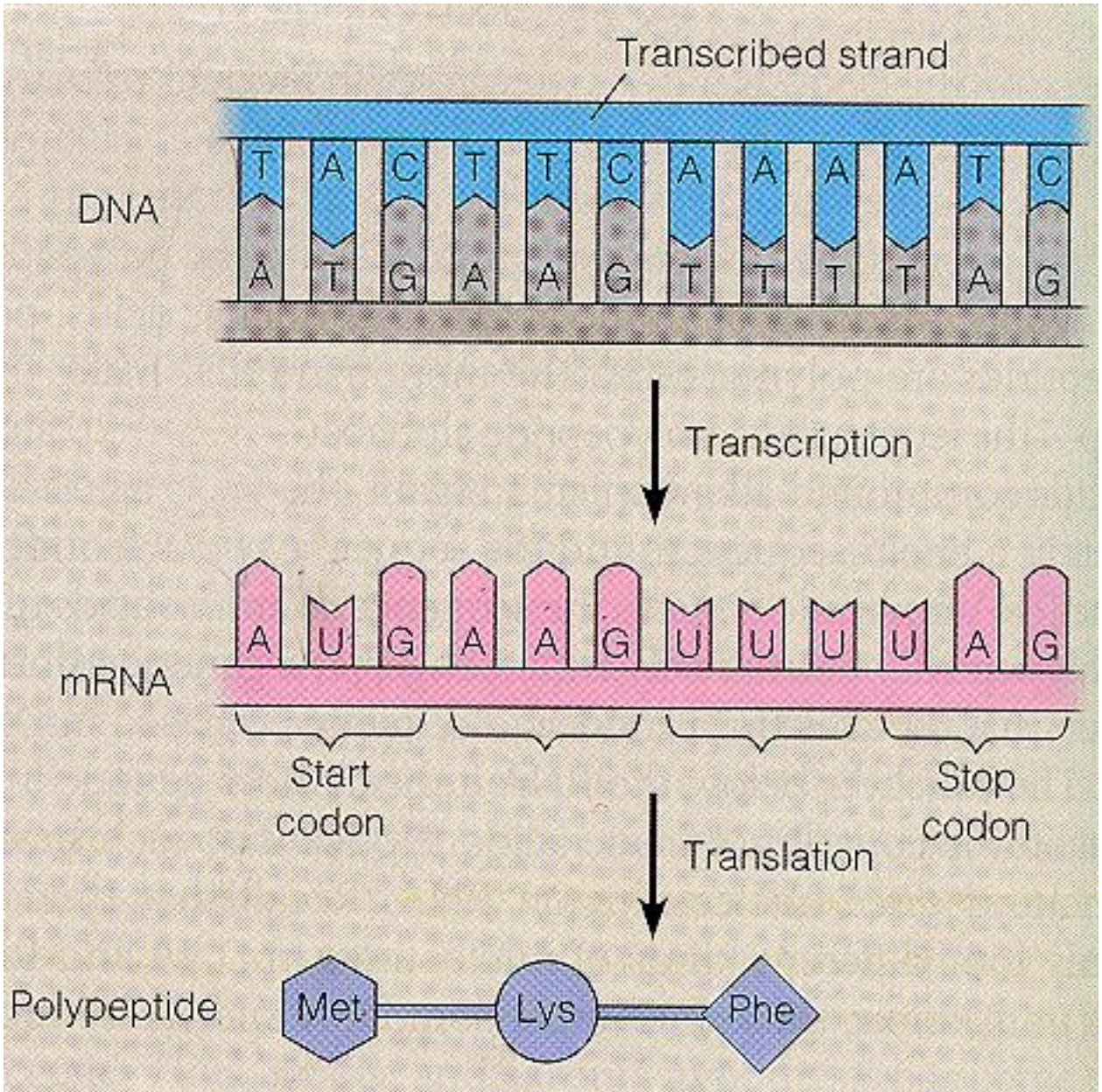
Genetic Code

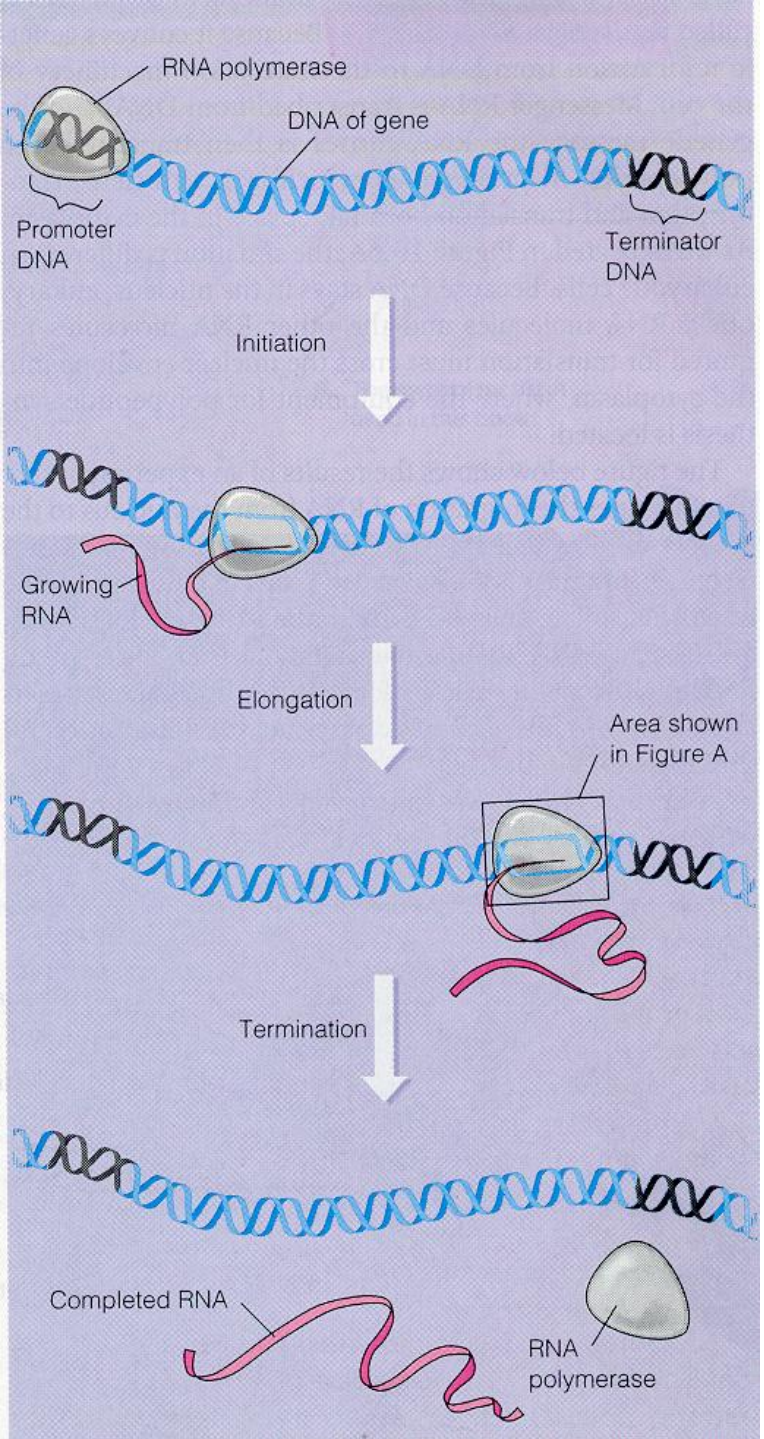
64 Codes for amino acids

Redundancy



From DNA to Proteins





Transcription of a Gene

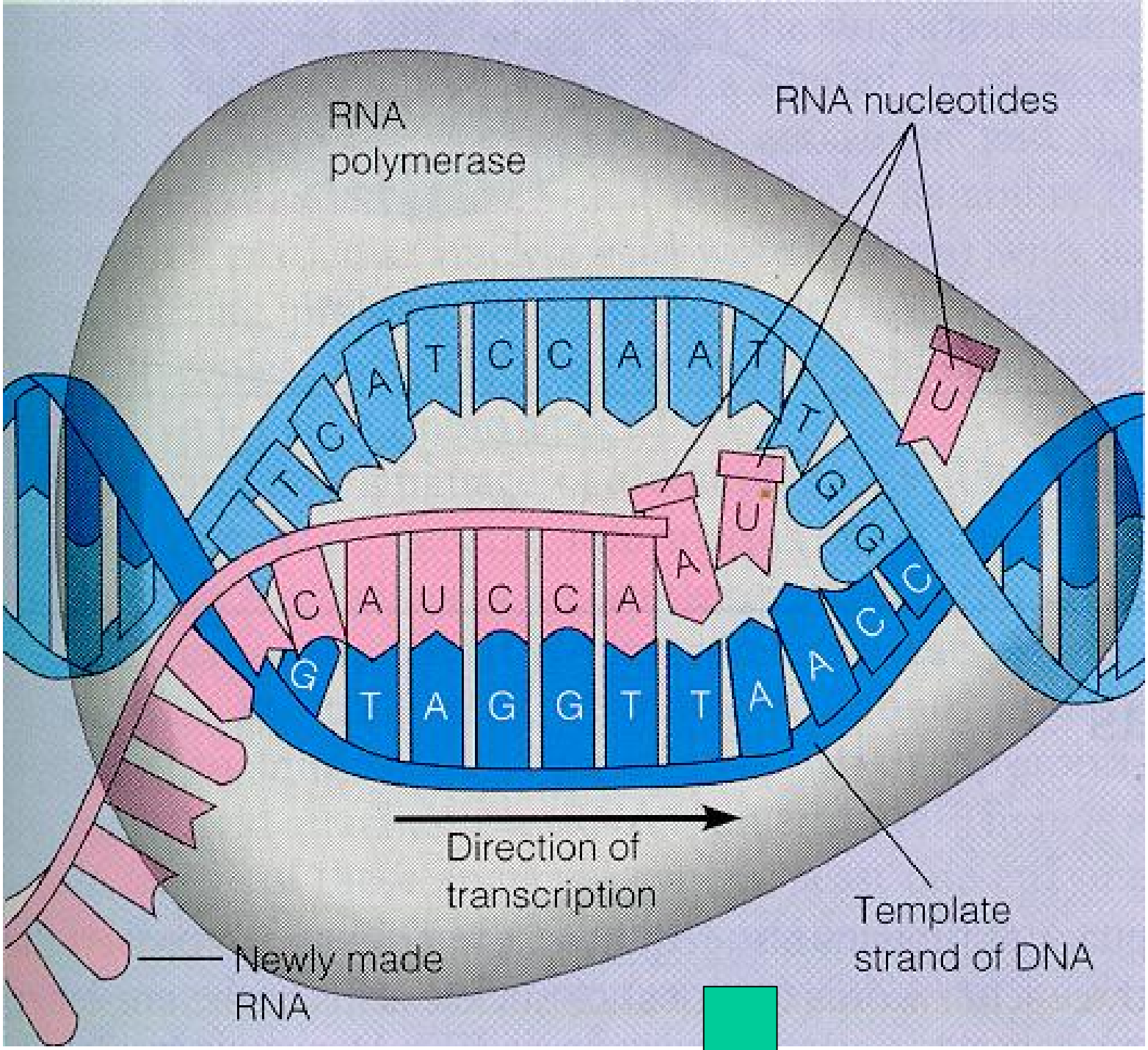
Promoter- a nucleotide sequence located next to the gene that signals the "start transcribing point".

Transcription divided into 3 phases

Initiation- occurs when RNA polymerase attaches to the promoter DNA.

Elongation- elongation of the RNA template

Termination- a special DNA sequence (terminator) that signal to RNA polymerase to stop transcribing and leads to its detachement from the RNA molecule and gene.


RNA
polymerase
RNA nucleotides
Direction of
transcription
Template
strand of DNA
Newly made
RNA

Genetic Messages are Translated in the Cytoplasm

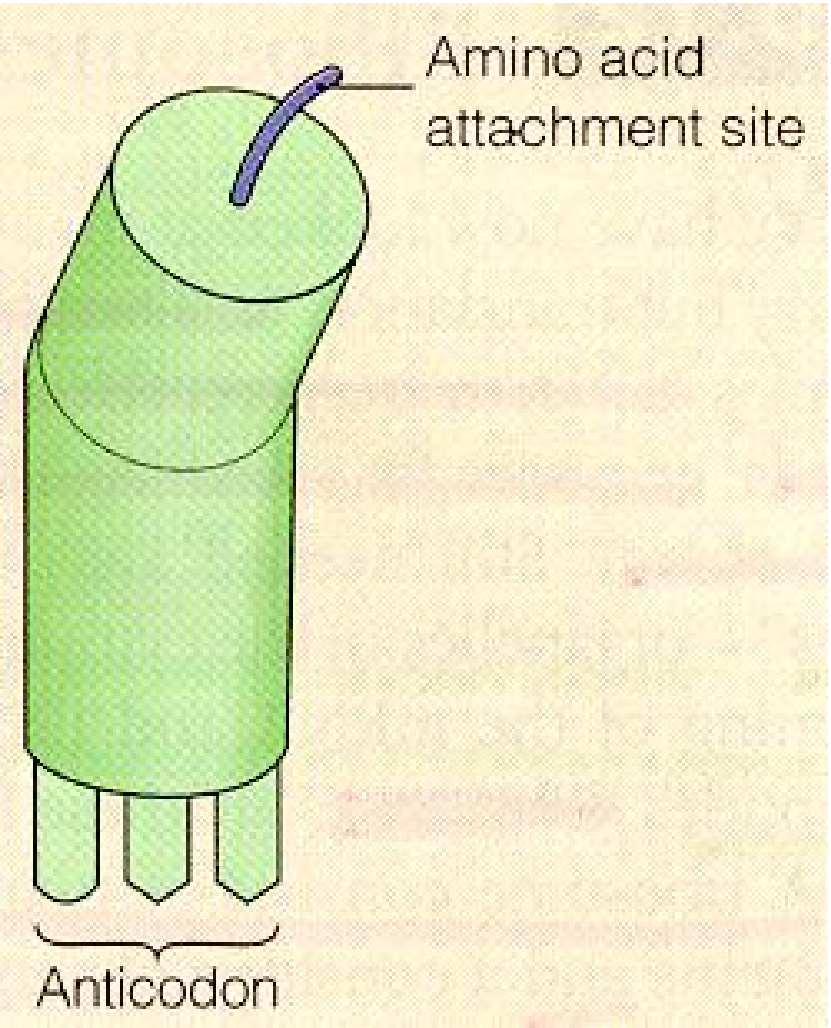
Machinery required for Translation

- Transfer RNA
- Ribosomes - organelles where polypeptide synthesis occurs
- Enzymes - a number of protein factors
- Chemical energy - ATP

Transfer RNA Molecule Serve as Interpreters During Translation

tRNA Molecules must carry out two distinct functions

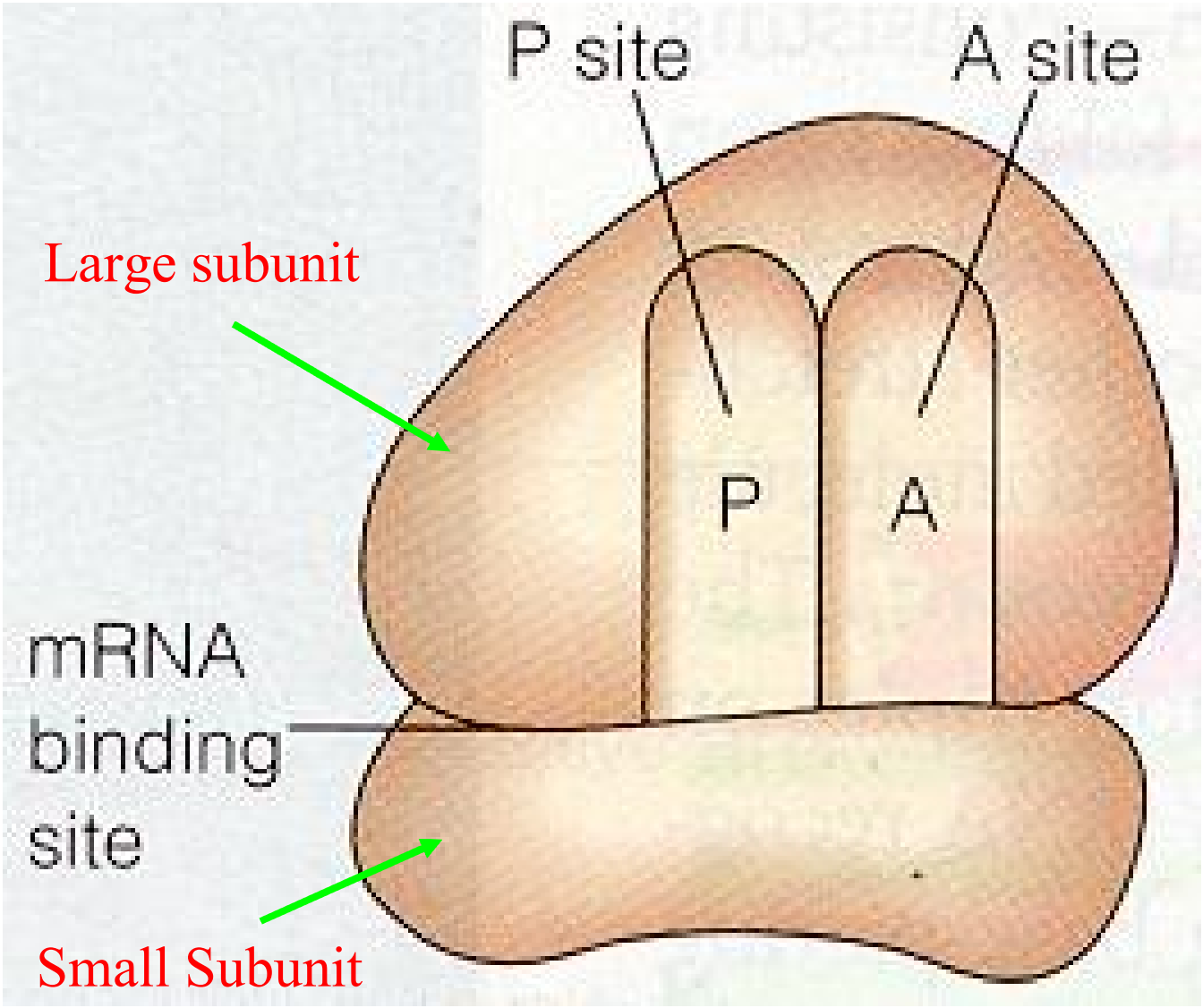
- Picking up the appropriate amino acids
- Recognizing the appropriate codons in mRNA

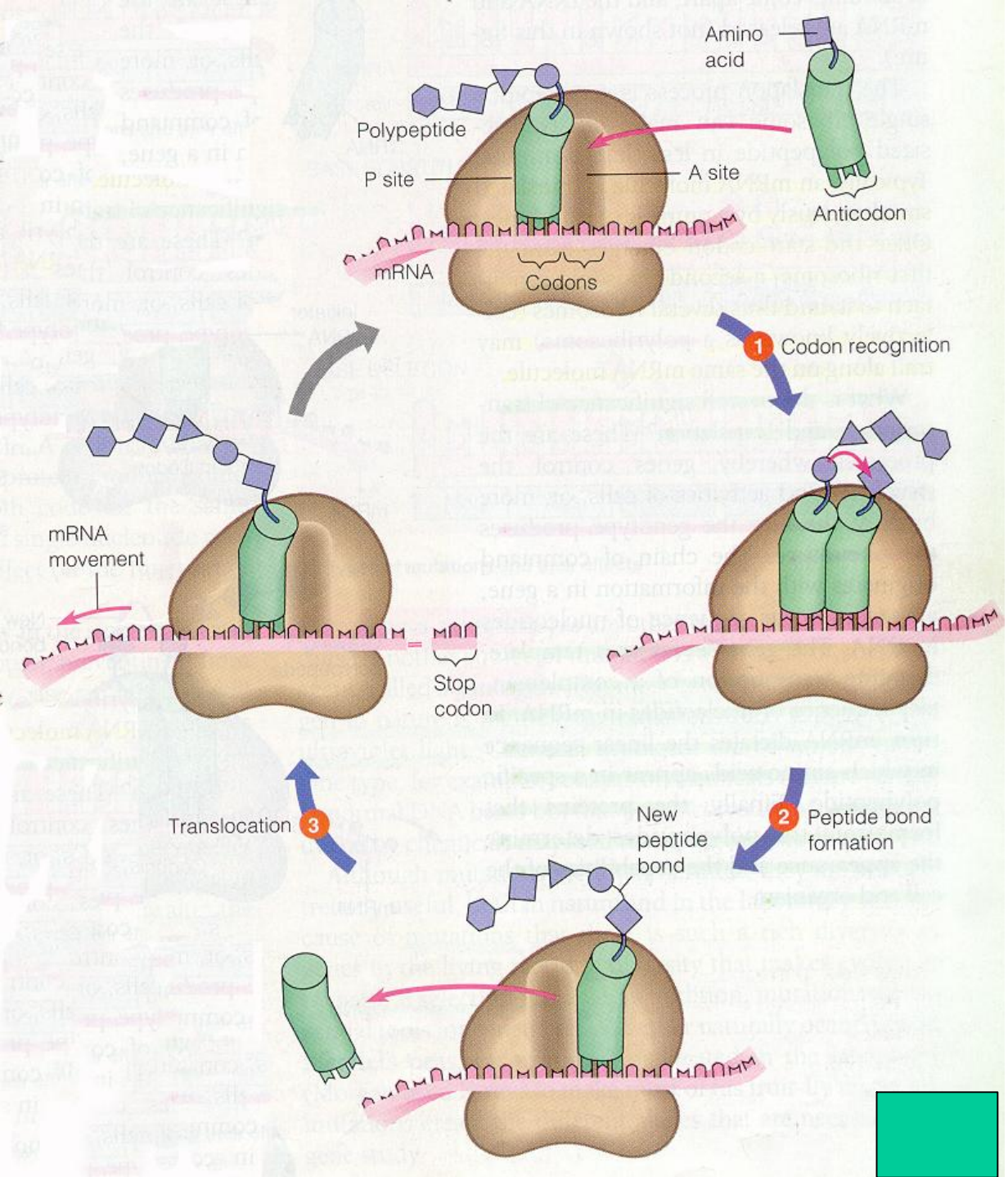


There is also a family of enzymes that insures the proper amino acid is attached to the right tRNA.

- There is a different enzyme for each amino acid .

Binding Sites of the Ribosome RNA (rRNA)



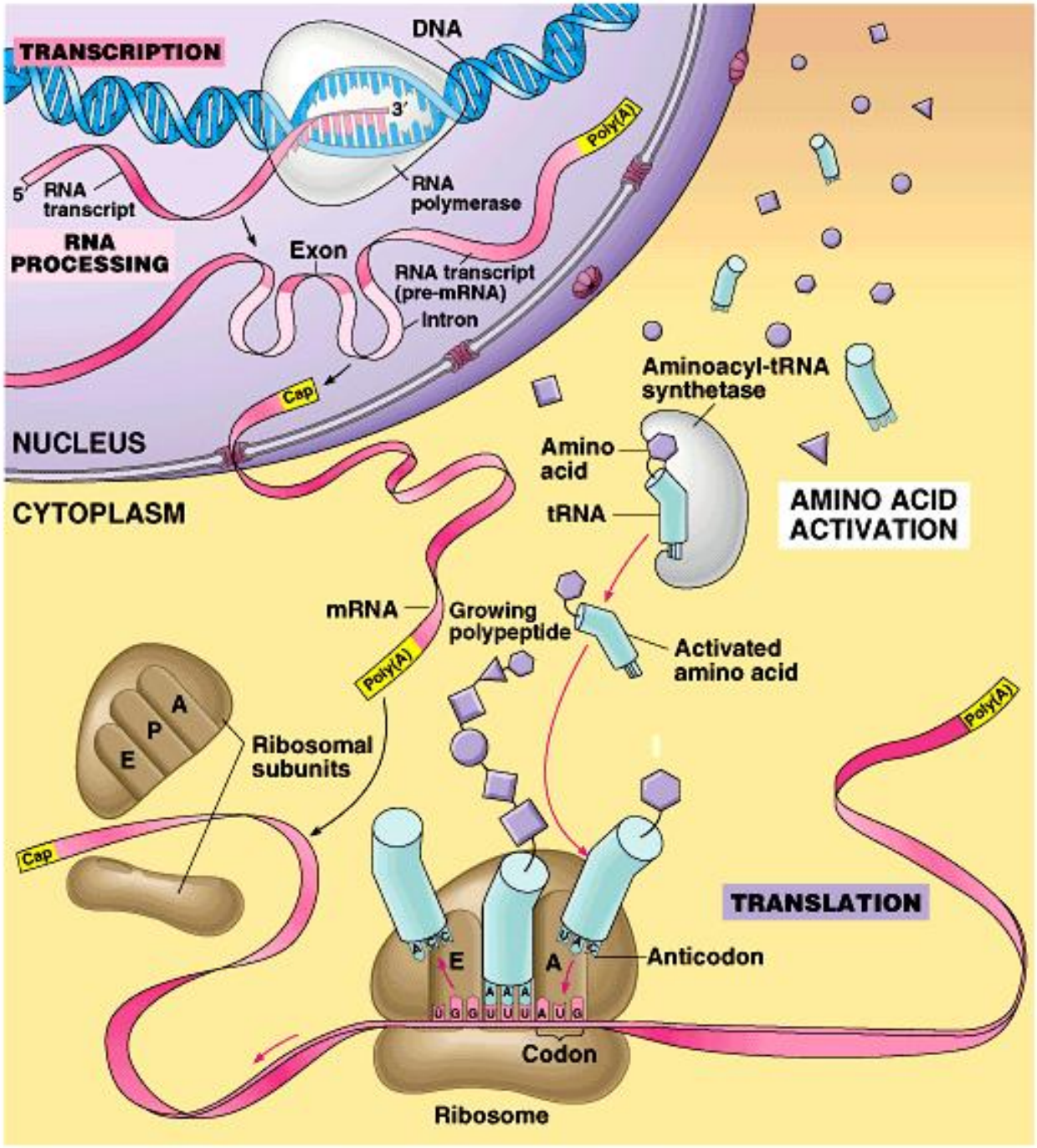


Translation can be divided into the same there phases as transcription

- initiation
- elongation
- termination

Each a.a. addition occurs in a three-step elongation process

- codon recognition
- peptide bond formation
- translocation



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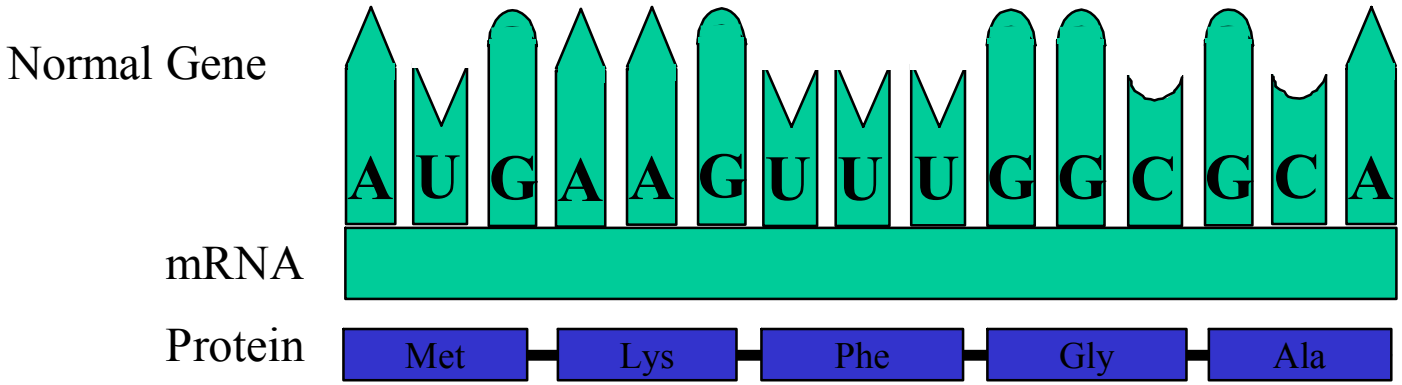
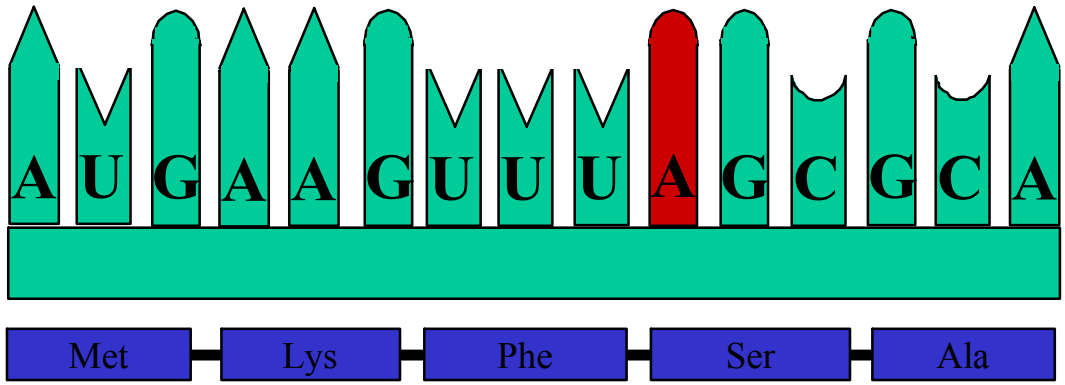
Mutations

- Any change in the nucleotide sequence of DNA
- Three major types of mutations
- alterations within a gene
- abnormal numbers of chromosomes
  - too many or too few of a certain chromosome
- abnormal chromosome structure
  - breakage leading to rearrangements

Mutation (continued)

- Alterations within a gene
  - **base substitutions-** the substitution of one nucleotide for another





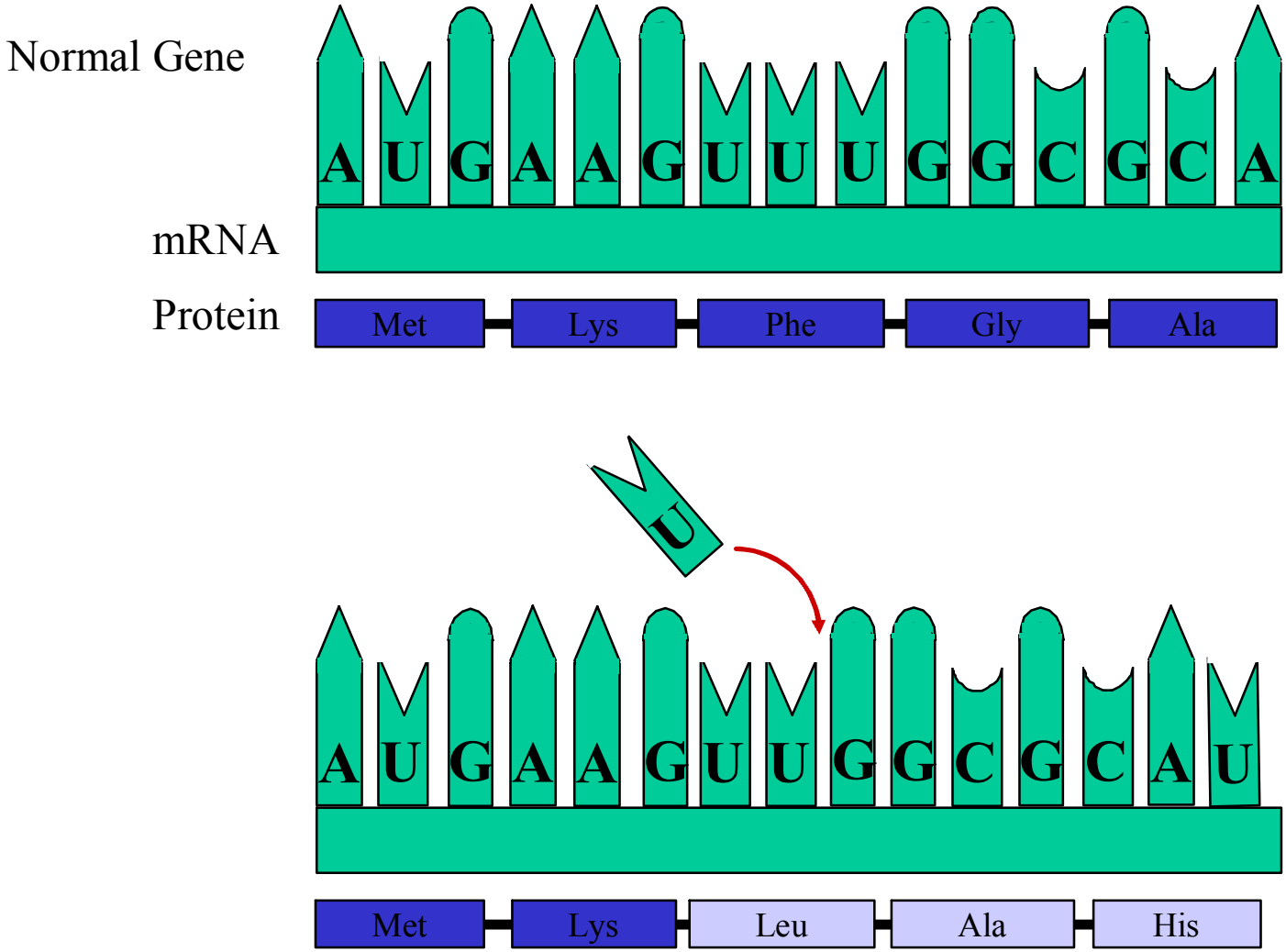
Base Substitutions

- Depending on how a base substitution is translated, it can result in
  - no change in the protein
  - in a insignificant change
  - in a change that might be crucial to life (sickle cell anemia)
  - occasional improvement that enhance the survival of the organism
- Some substitutions have no effect due to **redundancy** of the genetic code

Mutation (continued)

- Alterations within gene
  - **base deletions** and **insertions**- are often disastrous due to the alteration of the reading frame
  - all nucleotides down stream from the mutation will be regrouped into different codons

Base Insertions or Deletions



Mutagenesis

- The process of creating a mutation
- Spontaneous mutations- mutations resulting from **errors during DNA replication** or recombination and mutations of unknown cause
- Mutagens- the source of a mutation
  - can be physical, chemical agents, or biological

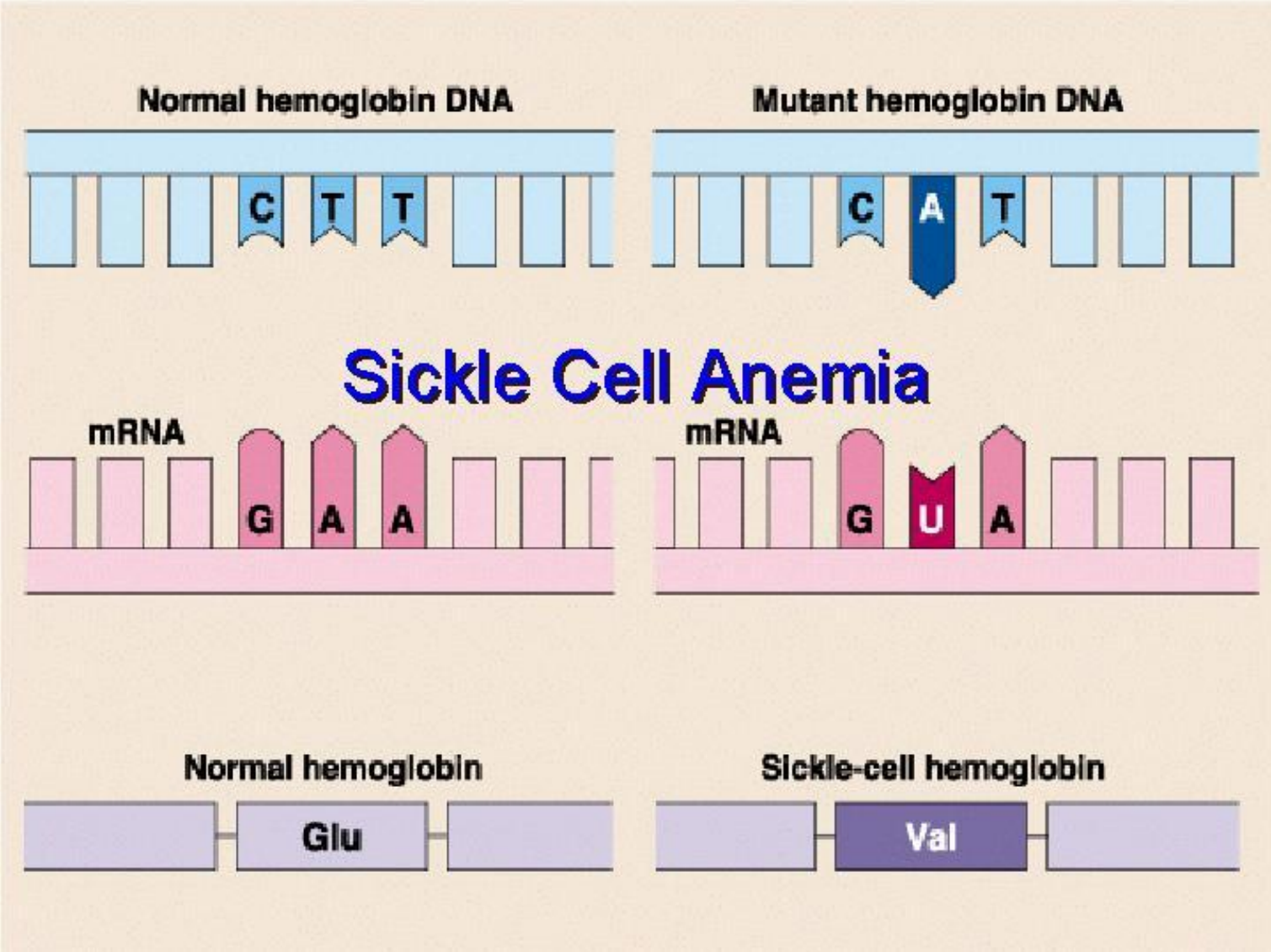
Mutagenesis

- Certain mutagens that are cancer causing are called **Carcinogens**
  - physical agents
    - high energy radiation is the most common physical agent
    - ultraviolet radiation

Mutagenesis

- Chemical agents
  - tobacco- known to cause more cases and types of cancer than any other single agent
    - cancer of the lung, bladder, kidne, mouth and throat, pancreas,stomach, and cervix
  - alcohol
    - cancer of the mouth and throat, and liver
- Biological agents
  - viruses
    - cancer of the cervix, liver, and blood

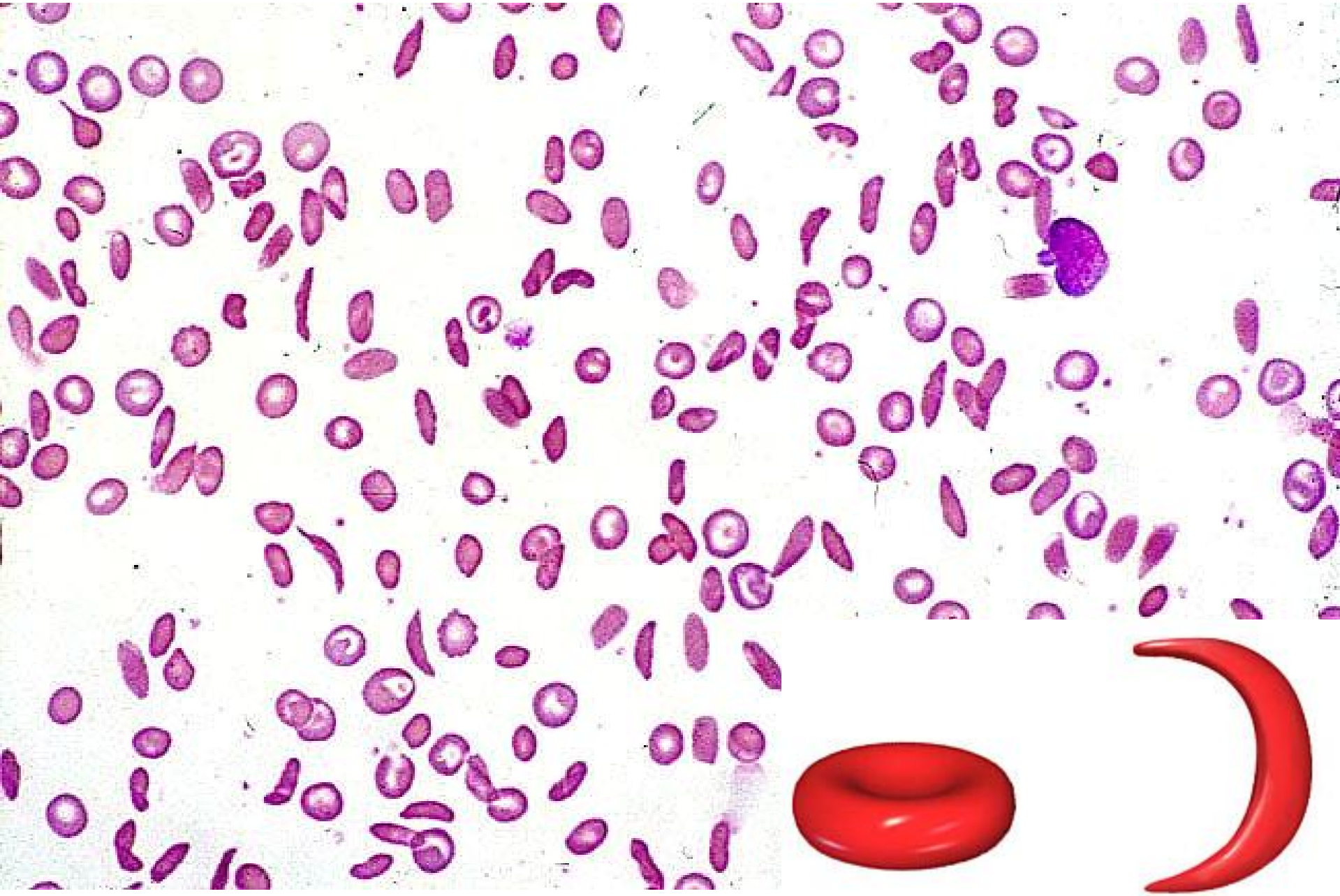
Point Mutation in Sickle Cell Anemia



Sickle cell anemia

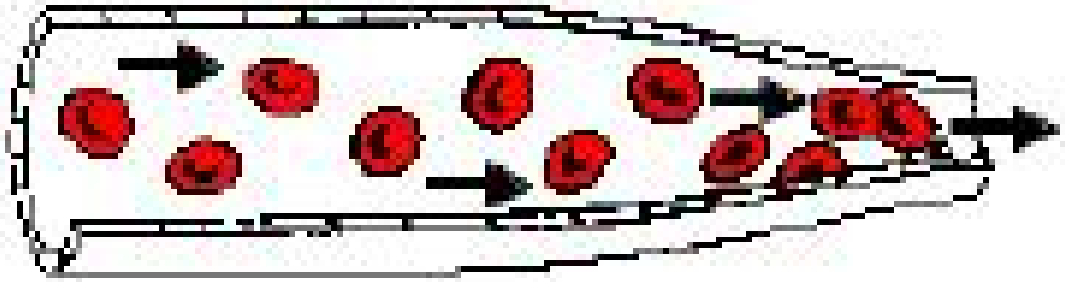
- In sickle cell anemia, red blood cells can become curved and pointy (like a sickle) and stiff.
- Sickle red blood cells don't always travel smoothly through the blood vessels, so traffic jams can occur on the highways.

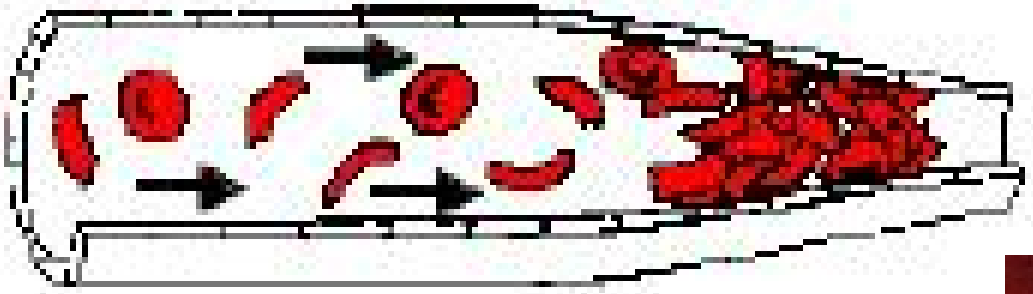
Sickle: a tool with a curved blade, for cutting grass

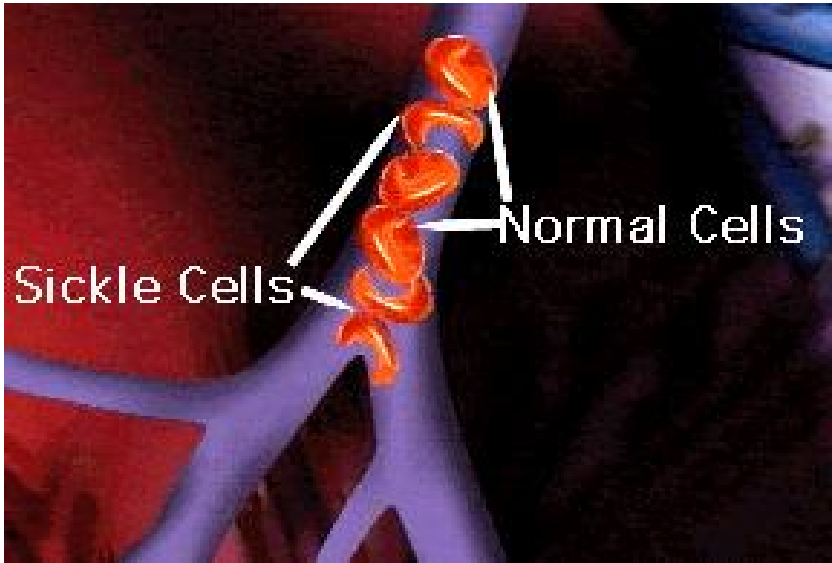


Normal red blood cell

Sickled red blood cell

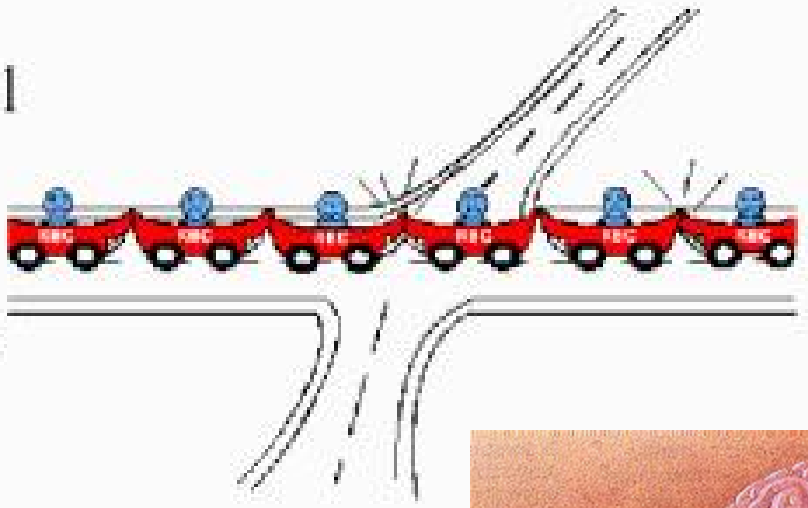


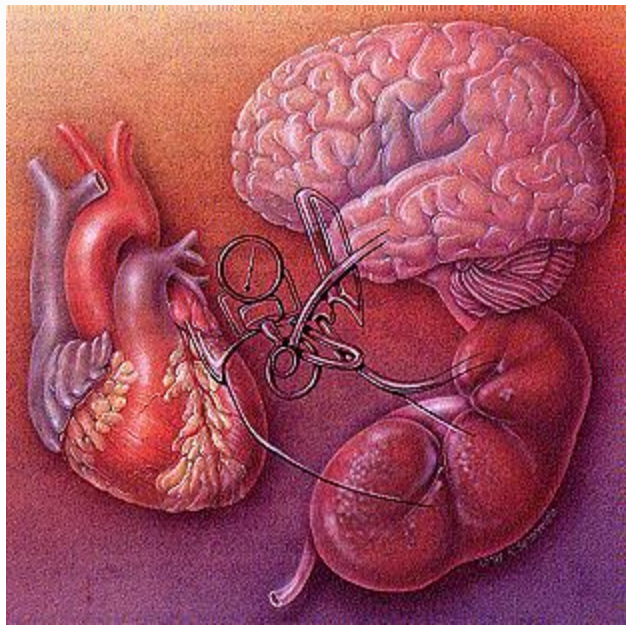



Normal Cells
Sickle Cells

Sickle cell traffic jams

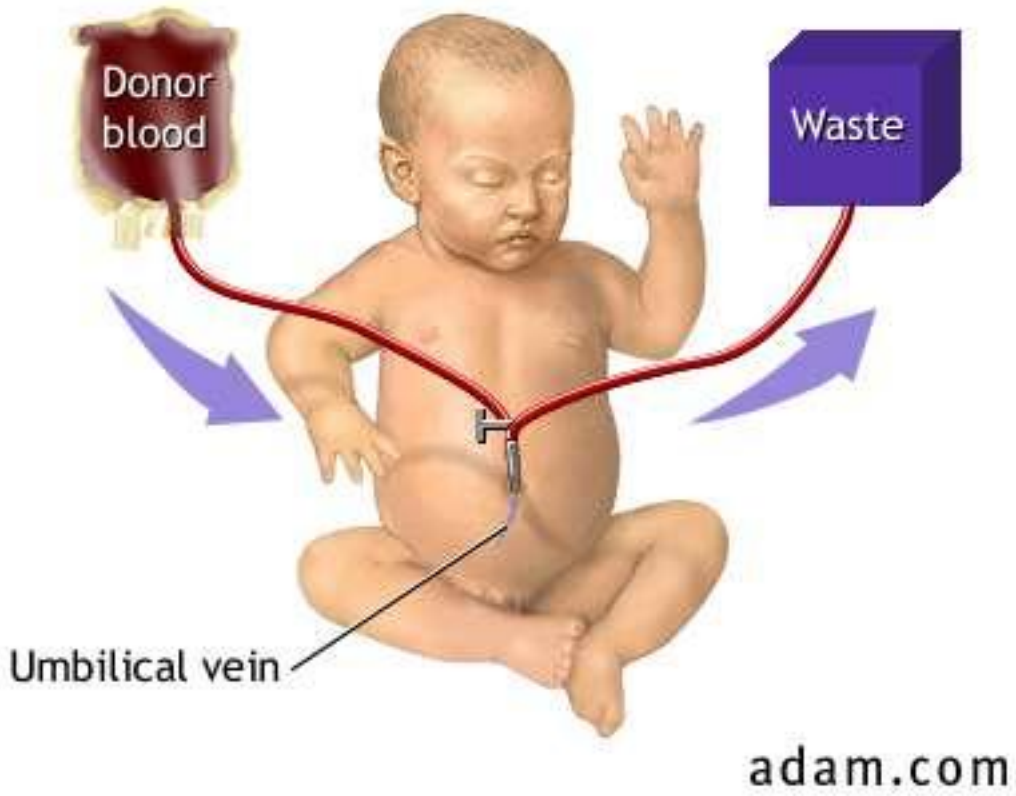
- If sickle cell traffic jams occur, parts of the body will not get enough blood or oxygen.
- This can cause problems in the bones, spleen, lungs, kidneys, or brain.





- The effects of sickle cell anemia vary from one person to another, ranging from mild to severe symptoms. However the basic problem is the same--the sickle cell shaped red blood cells block narrow blood vessels and impede the flow of blood.
- Sickle Cell Crisis: Sickle cell crisis refers to a sudden increase of anemia, pain, fever, and sometimes shortness of breath. This is can be caused by anything that reduces the amount of oxygen in the blood, such as vigorous exercise, high altitudes, or illness.
  - Anemia: Because of the reduction in oxygen transport, people may feel fatigued, become pale or short of breath.
  - Pain: Pain can occur unpredictably in any body organ or joint, wherever the sickle shaped blood cells block oxygen flow to the tissues. Pain often occurs in the long bones and abdomen, sometimes severe enough to induce vomiting.
  - Jaundice: Yellowing of the skin and eyes due to the rapid breakdown of red blood cells.
  - Infections: Sickled cells cause damage to the spleen and prevent the spleen from destroying bacteria in the blood. Because the spleen helps fight infection, affected people are more likely to develop pneumococcal pneumonia and other infections.
  - Stroke: The defective hemoglobin damages the membranes of the red blood cells, causing them to stick to blood vessel walls. This can result in narrowed or blocked vessels in the brain and lead to a stroke.
  - Acute Chest Syndrome: In children, sickle cell crisis may include severe chest pain and difficulty in breathing. The cause of the chest syndrome is unknown but is thought to be the result of blocked vessels.
  - Hand-foot Syndrome: Poor circulation to the small blood vessels of the skin of the extremities may cause tissue damage. This may manifest as pain, swelling, or sores.

Exchange Transfusion



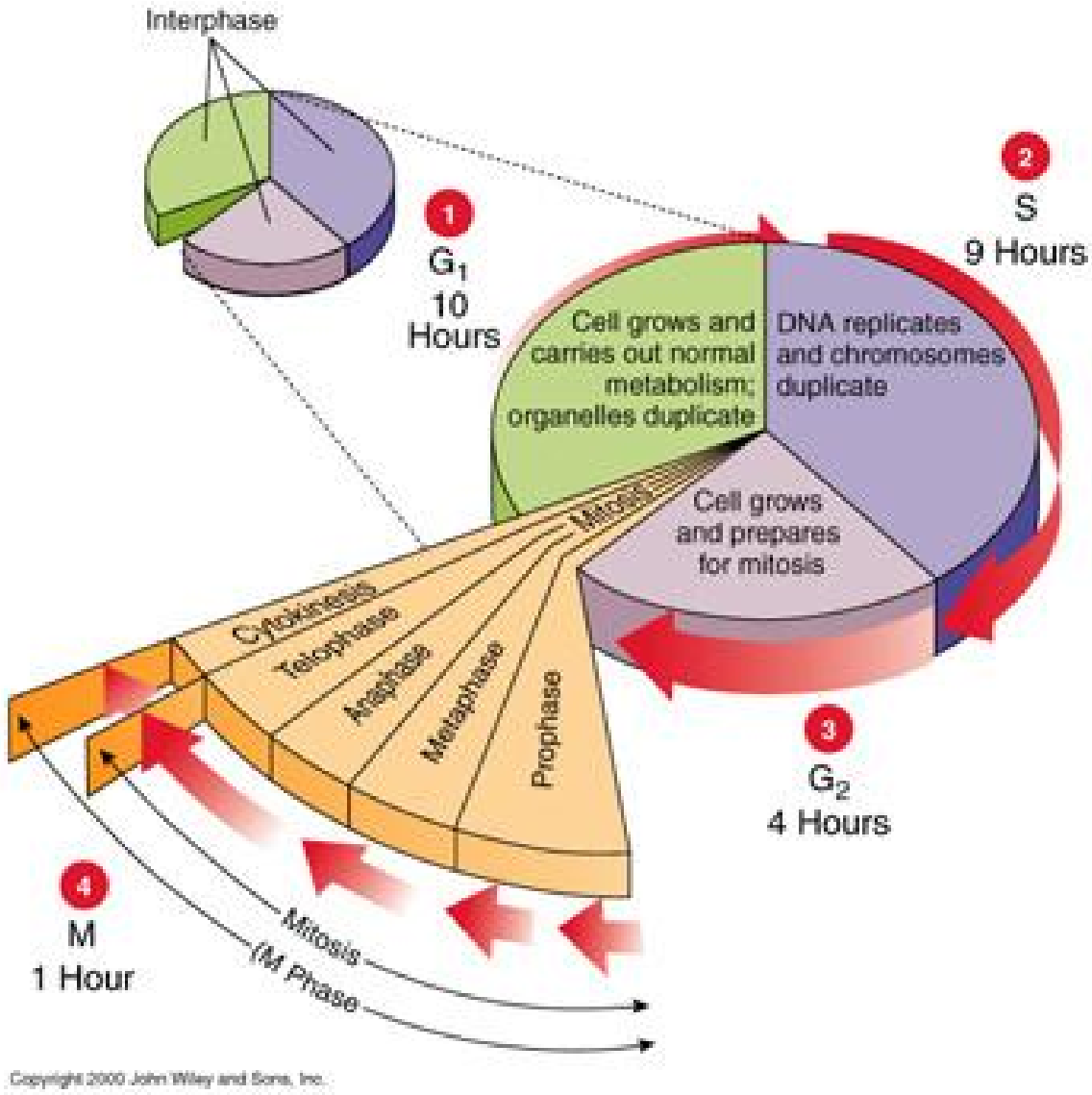
Somatic Cell Division

Includes all body cells except the sex cells

- cell division is for growth and repair
- starting cell (parent cell) divides to produces two identical cell (daughter cells)
- the process of division is called **mitosis**

Mitosis

- all somatic cells contain 46 chromosomes (23 pairs homologous pairs)
- cell must duplicate all genetic material and organelles

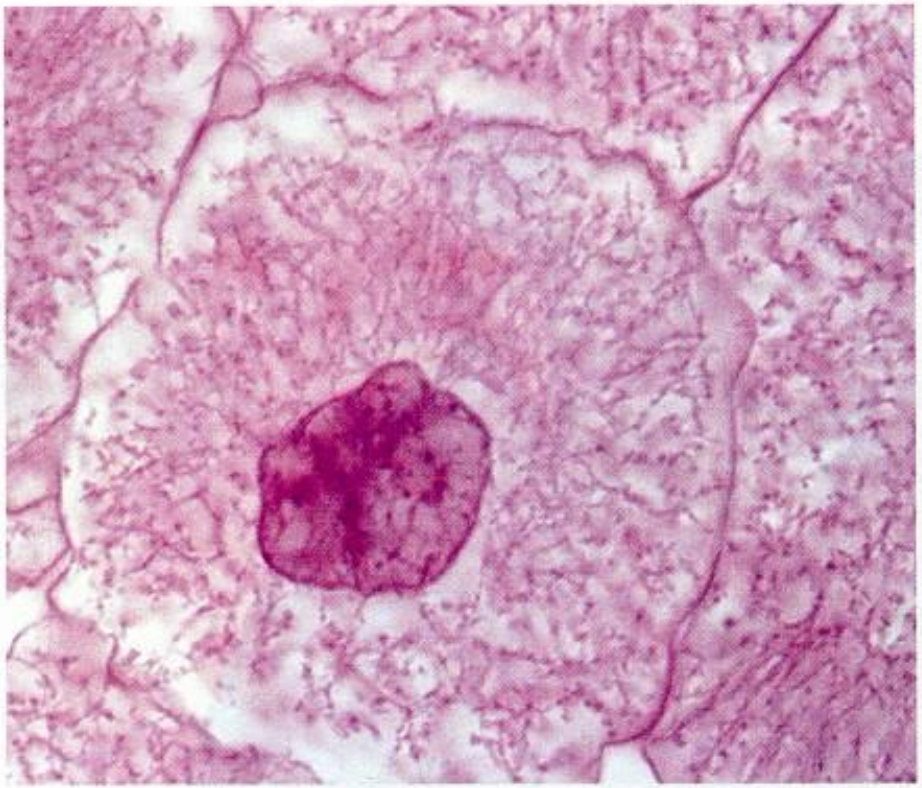


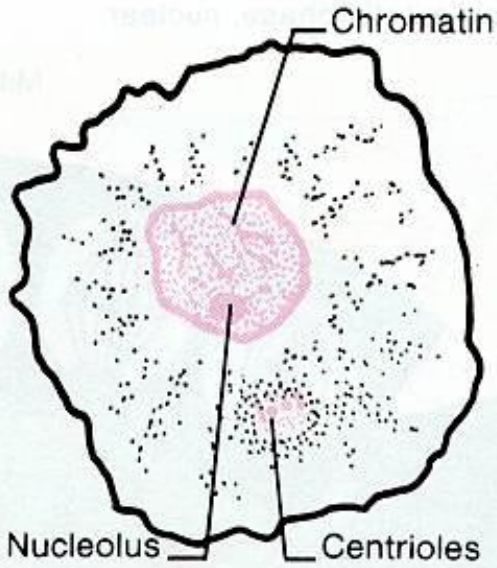
Cell Cycle

Cell Cycle

- The length of the cell cycle varies greatly from one cell type to another
  - Stomach and skin divide rapidly, whereas bone and cartilage slowly, and muscle and nerve cell, not at all
  - G_0- when the cell ceases to divide to enter a "rest" phase (may last for years)

Interphase





(a) Interphase

The chromosomes are in an extended form and seen as chromatin in the electron microscope. The nucleus is visible.

In “S” Phase of the Cell Cycle, the DNA Replicates

Figure C-1: Location of Genes in DNA

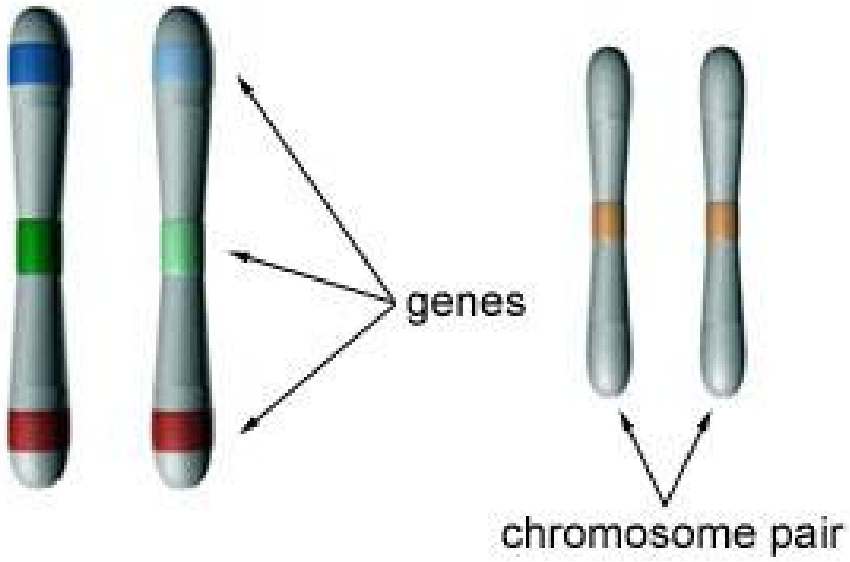
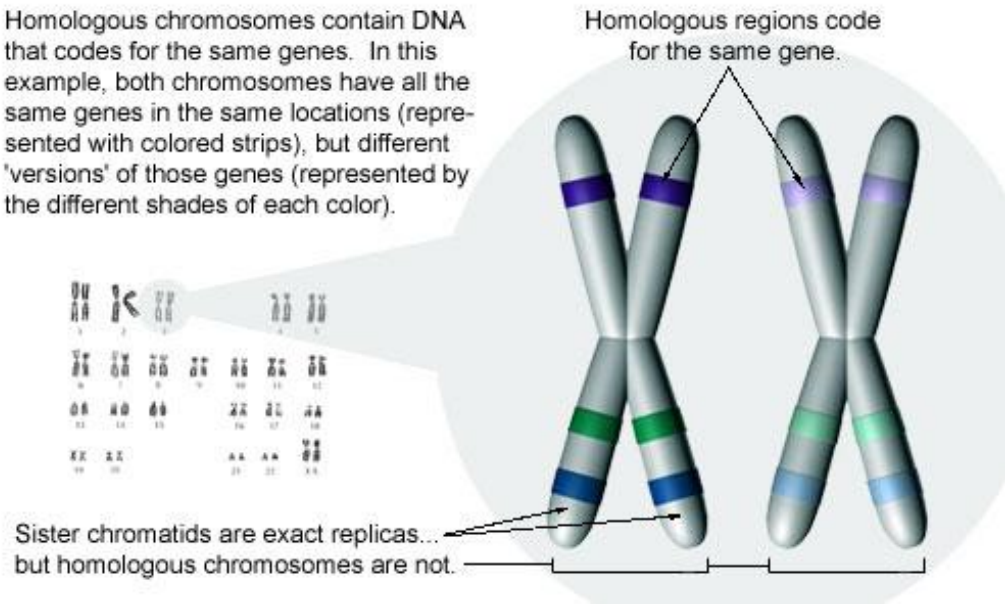
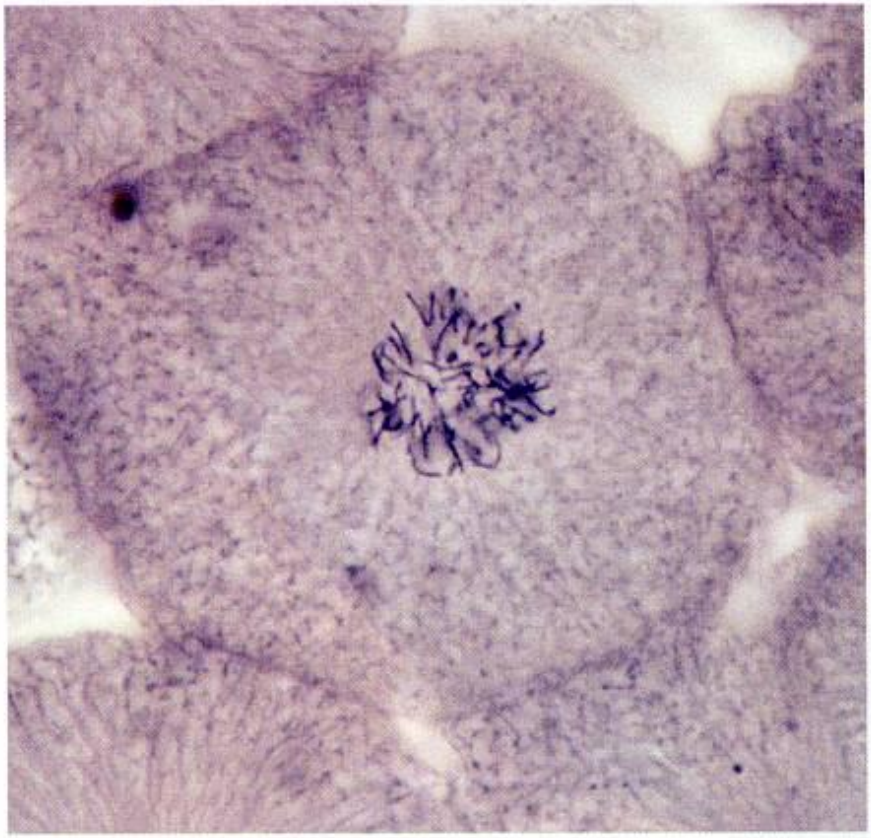


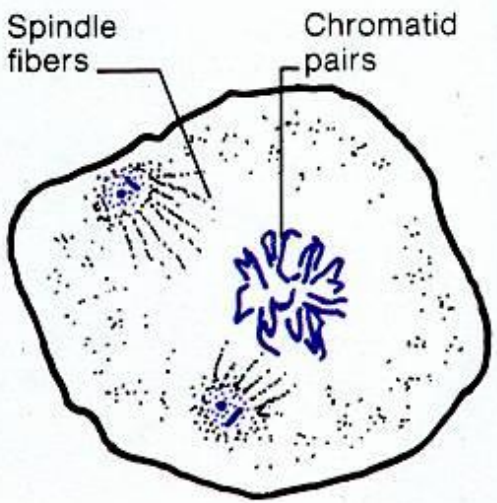
Figure B-11: Homologous Chromosomes

Homologous chromosomes contain DNA that codes for the same genes. In this example, both chromosomes have all the same genes in the same locations (represented with colored strips), but different 'versions' of those genes (represented by the different shades of each color).



Prophase

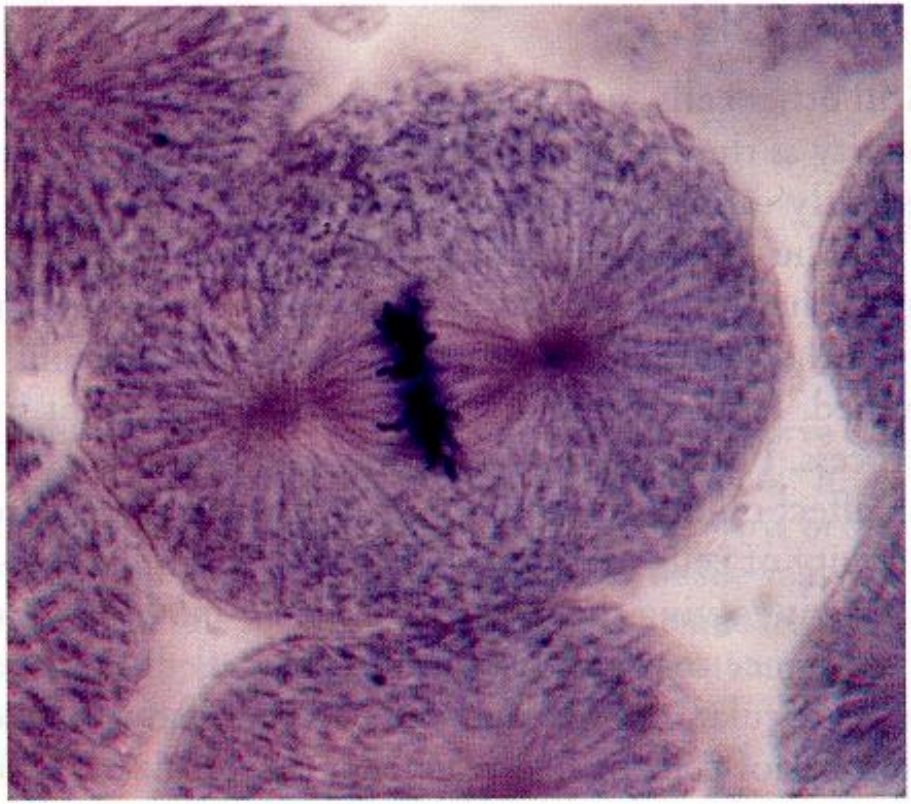


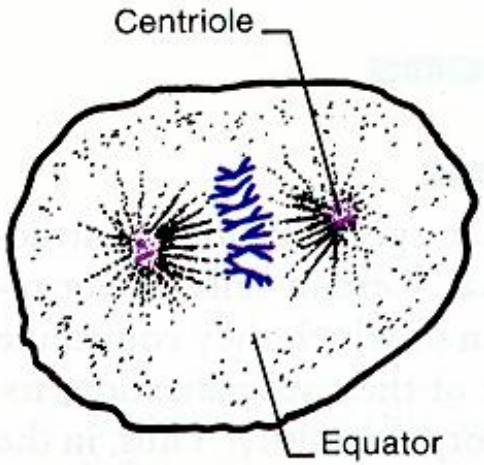


(b) Prophase

The chromosomes are seen and observed to consist of two chromatids joined together by a centromere.
The centrioles move apart toward opposite poles of the cell.
Spindle fibers are produced and extend from each centriole.
The nuclear membrane starts to disappear.
The nucleolus is no longer visible.

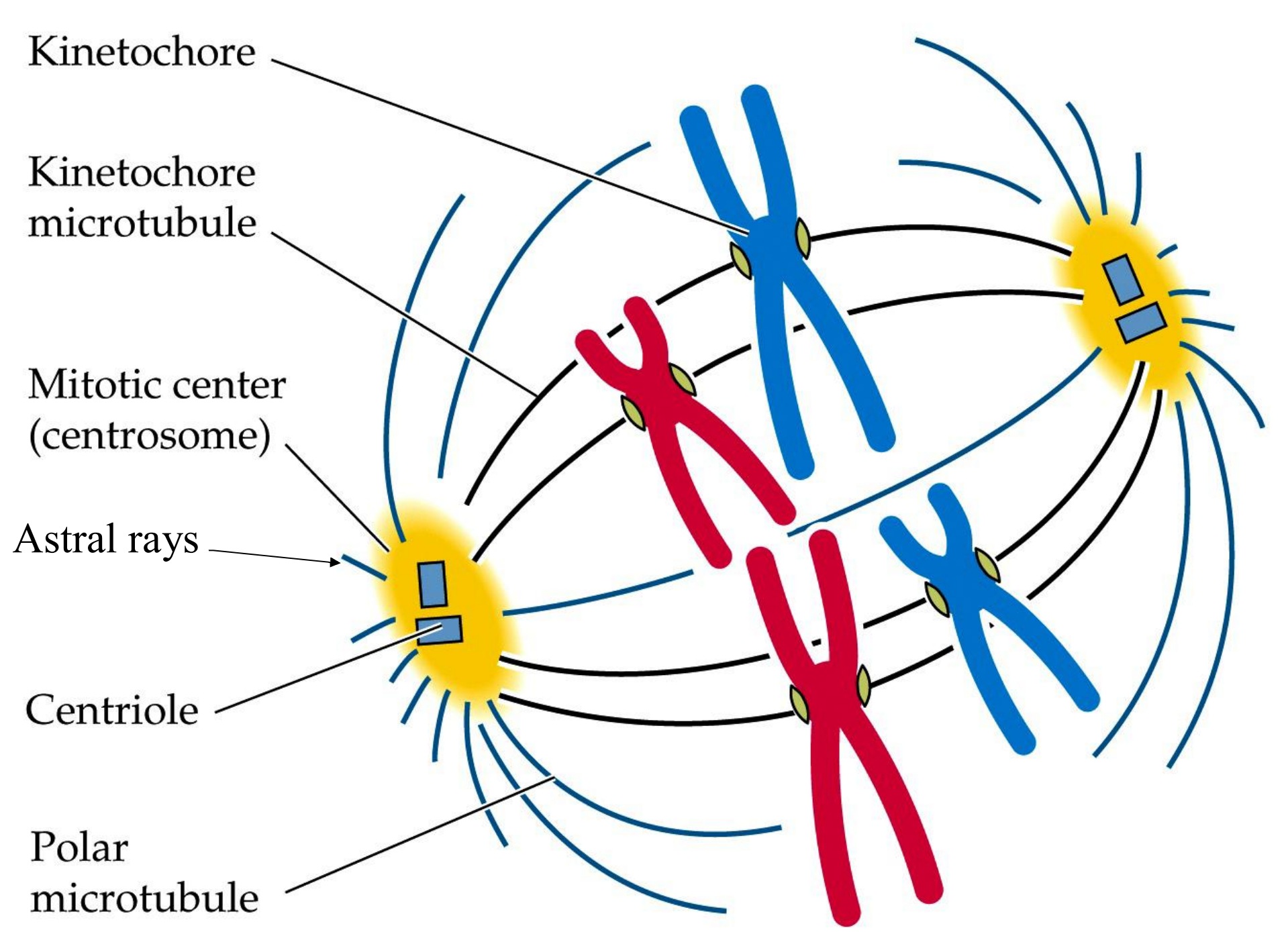
Metaphase





(c) Metaphase

The chromosomes are lined up at the equator of the cell.
The spindle fibers from each centriole are attached to the centromeres of the chromosomes.
The nuclear membrane has disappeared.



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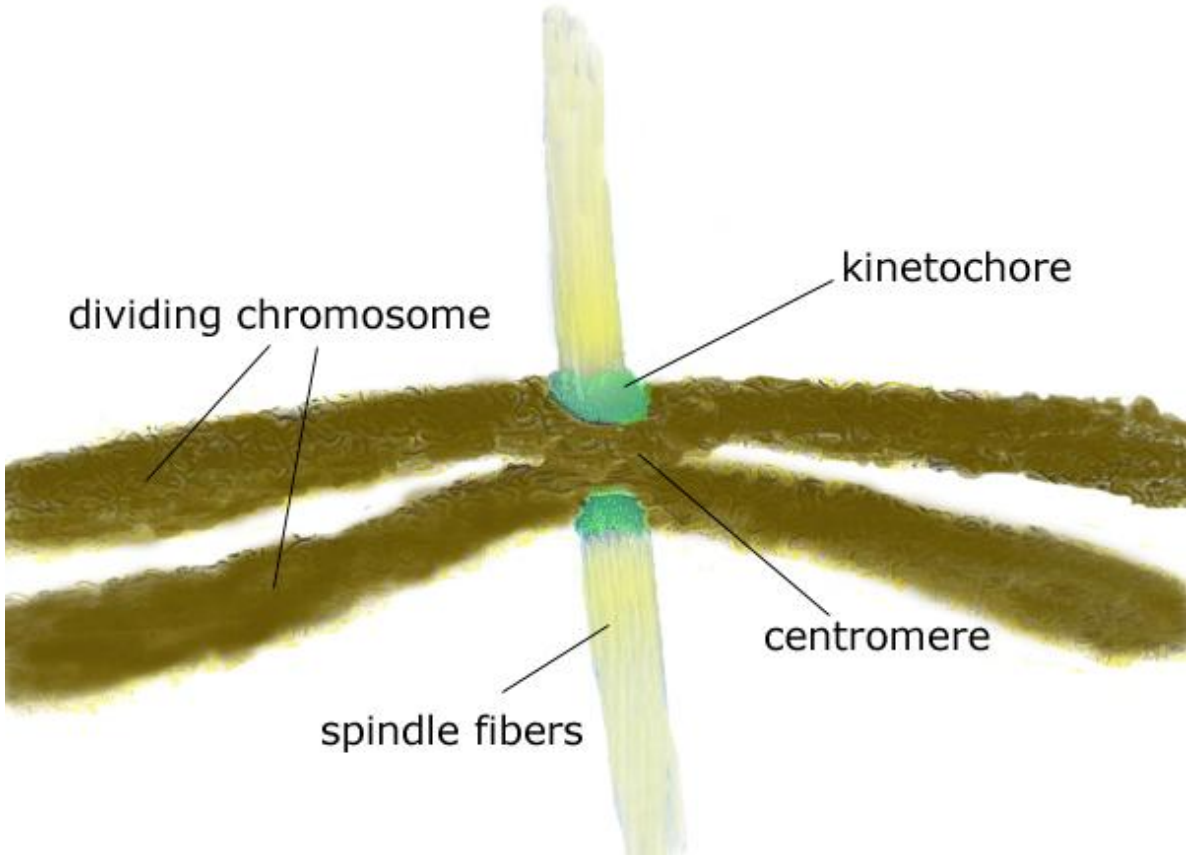
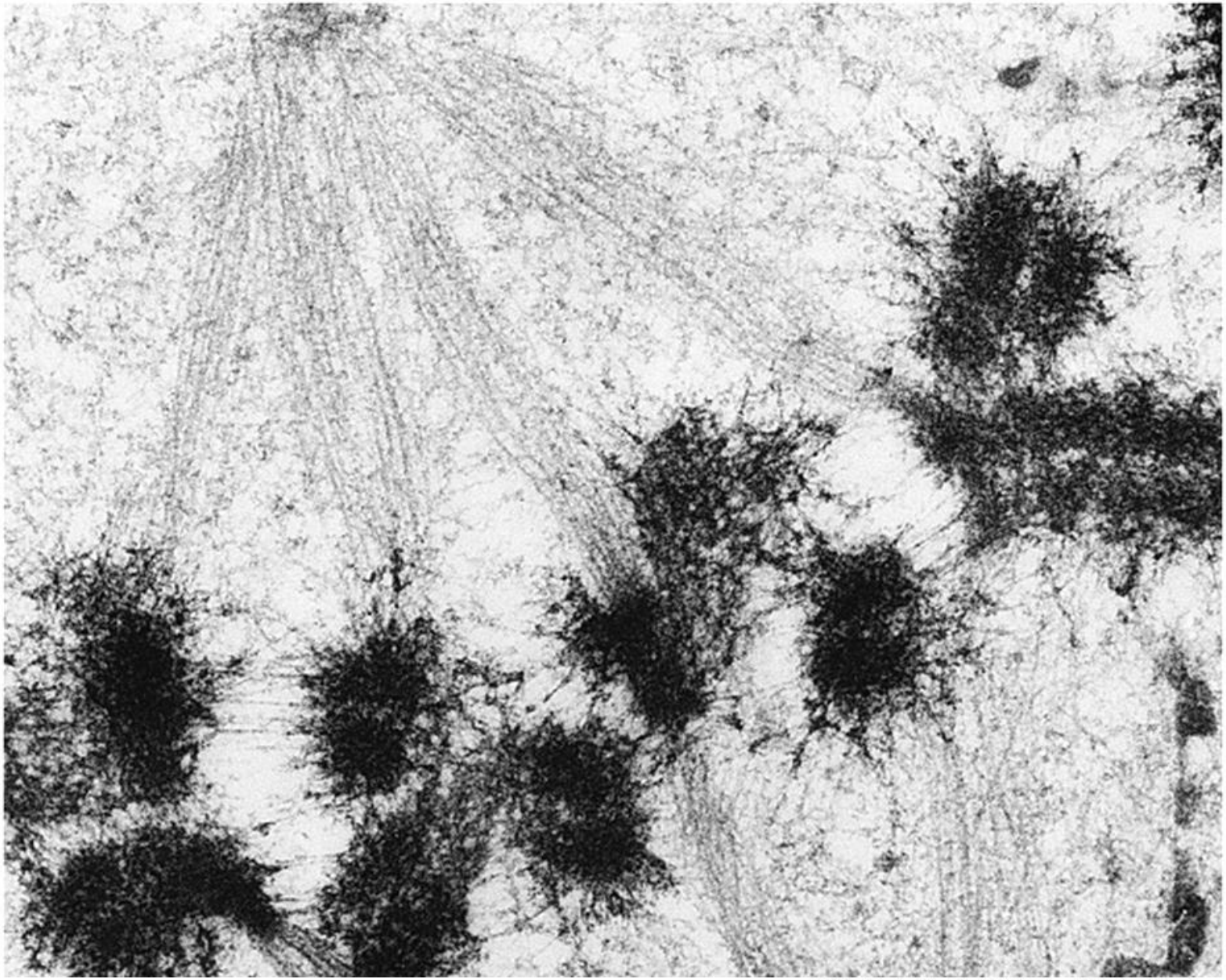
Mitosis

- The **centromere** joins the two sister chromatids.
- During mitosis a protein structure called a **Kinetochore** forms on each side of the centromere.
- The **spindles** attach to the Kinetochore.
- The spindles then pull the sister chromosomes apart.





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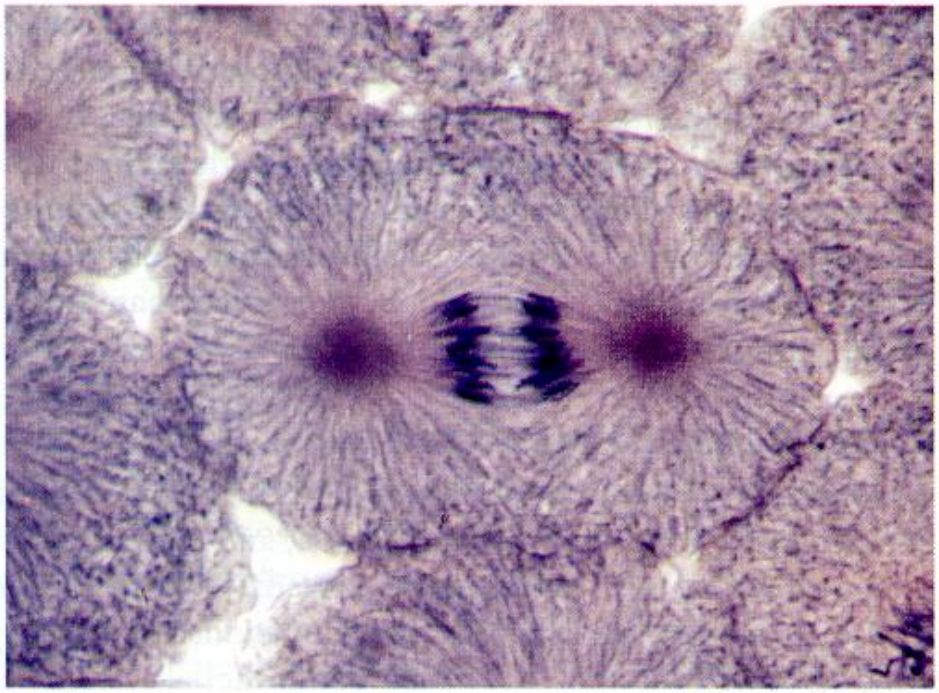
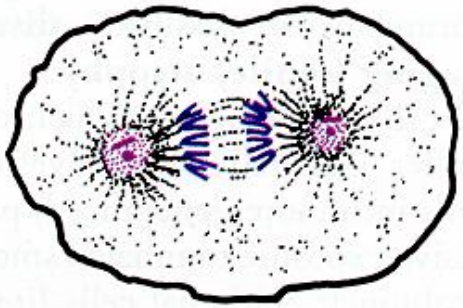
Anaphase

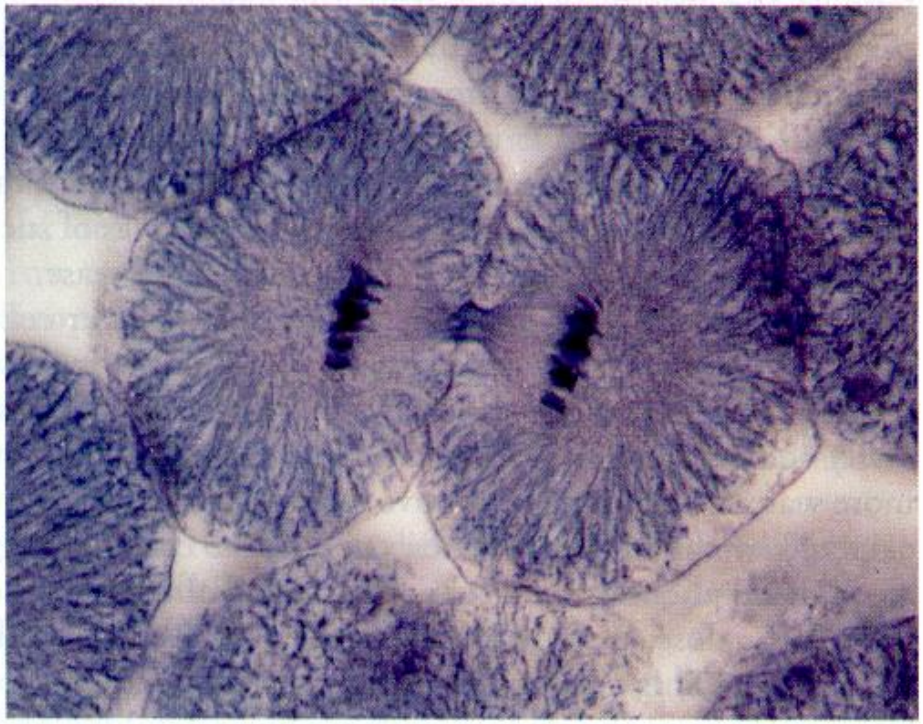


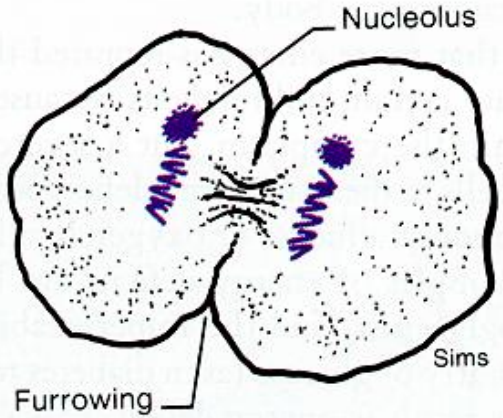


(d) Anaphase

The centromeres split, and the sister chromatids separate as each is pulled to an opposite pole.

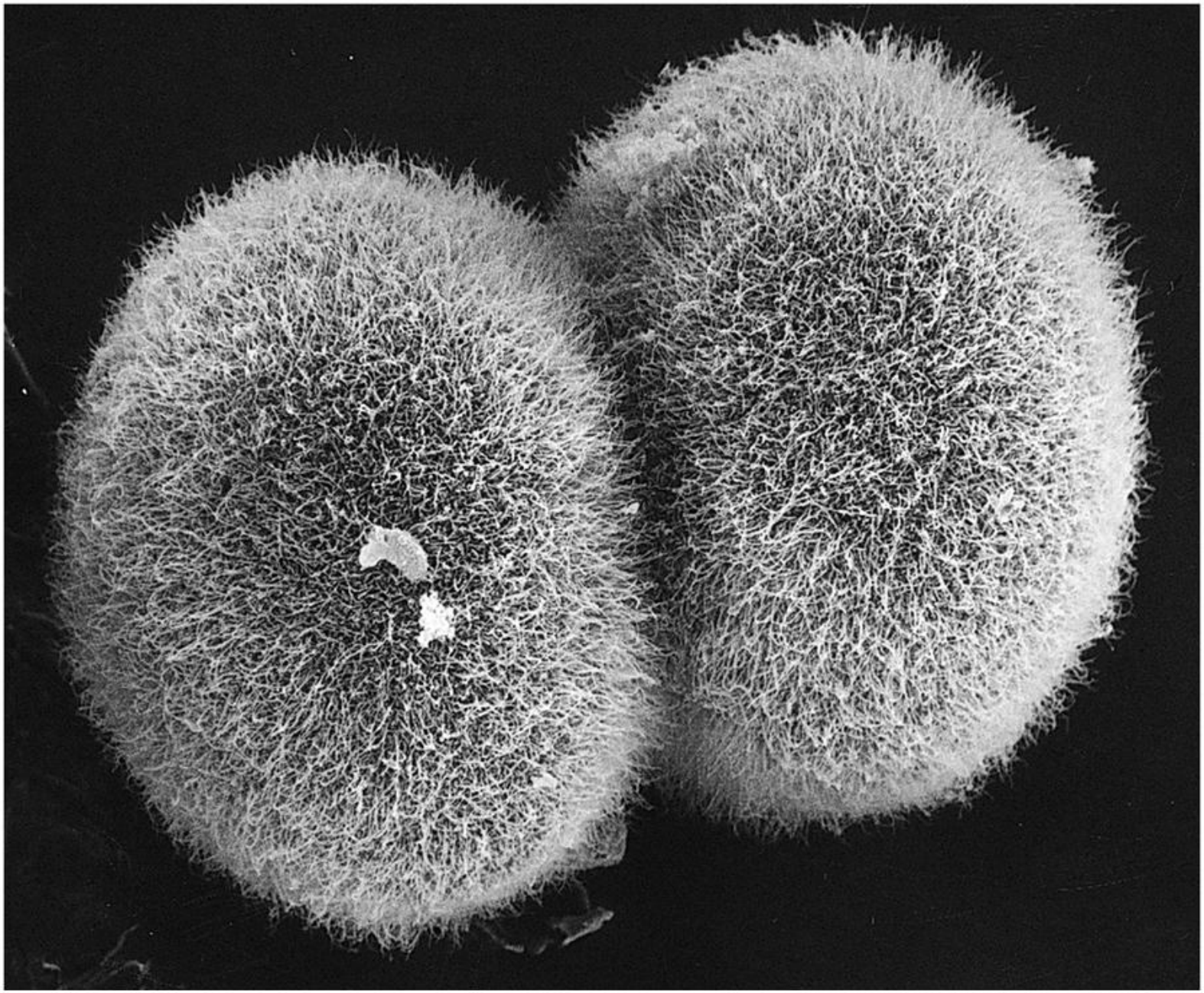
Telophase/Cytokinesis





(e) Telophase

The chromosomes become longer, thinner, and less distinct.
New nuclear membranes form.
The nucleolus reappears.
Cell division (cytokinesis) is nearly complete.



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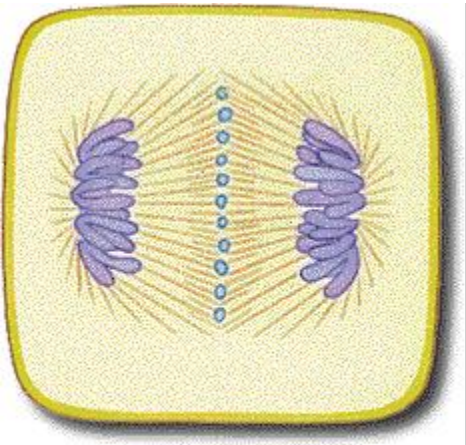

vesicles at
spindle equator

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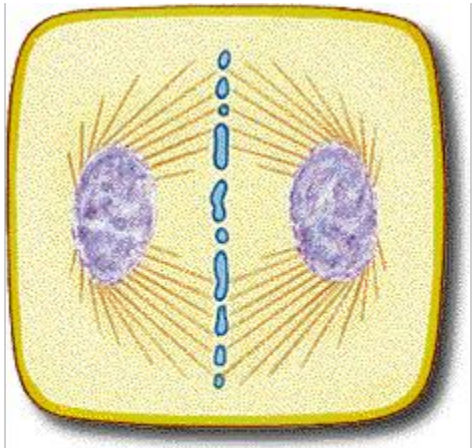

vesicles fusing

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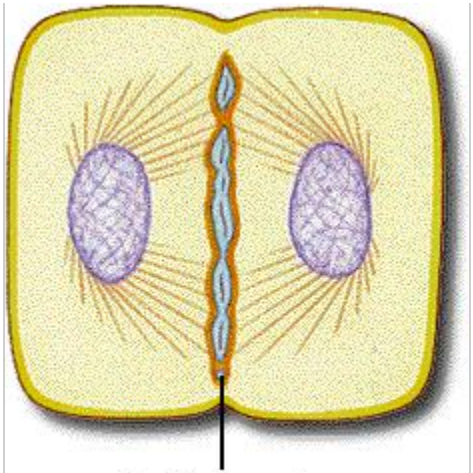

cell plate growing

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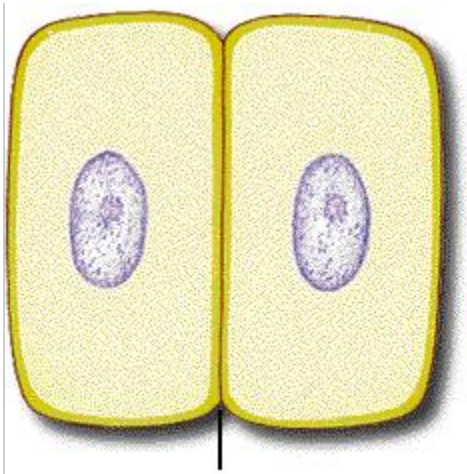

new primary cell wall

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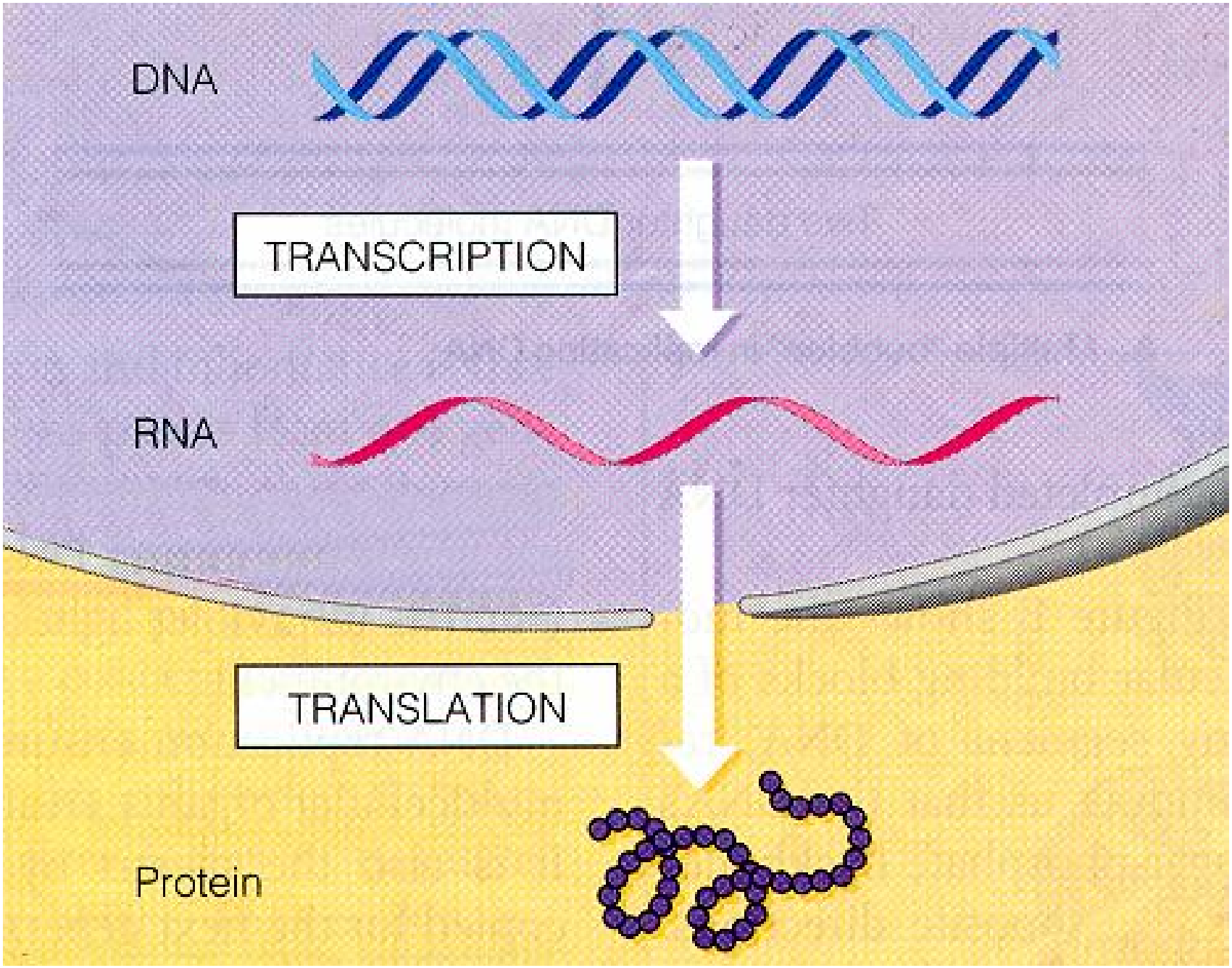
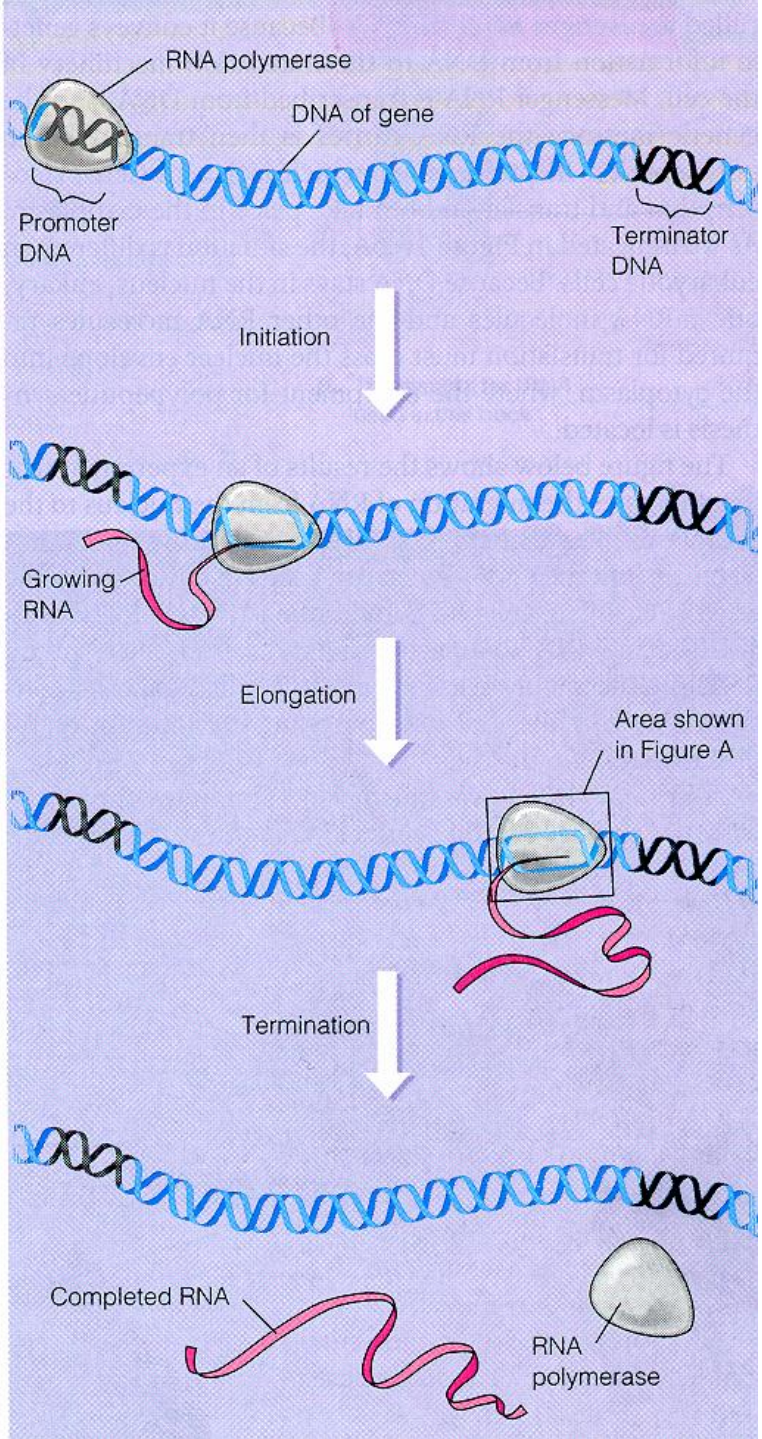
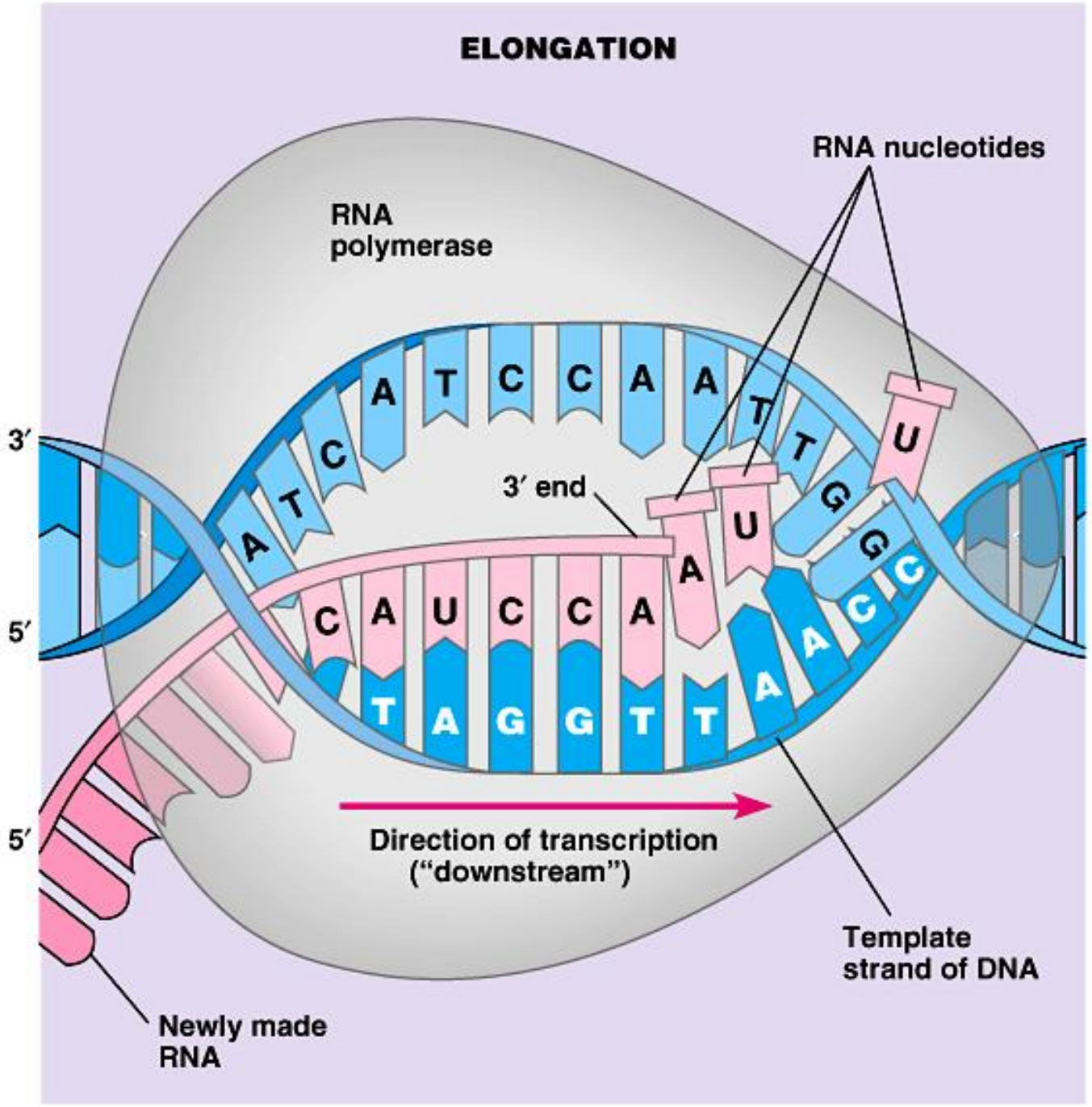

DNA
TRANSCRIPTION
RNA
TRANSLATION
Protein

Transcription





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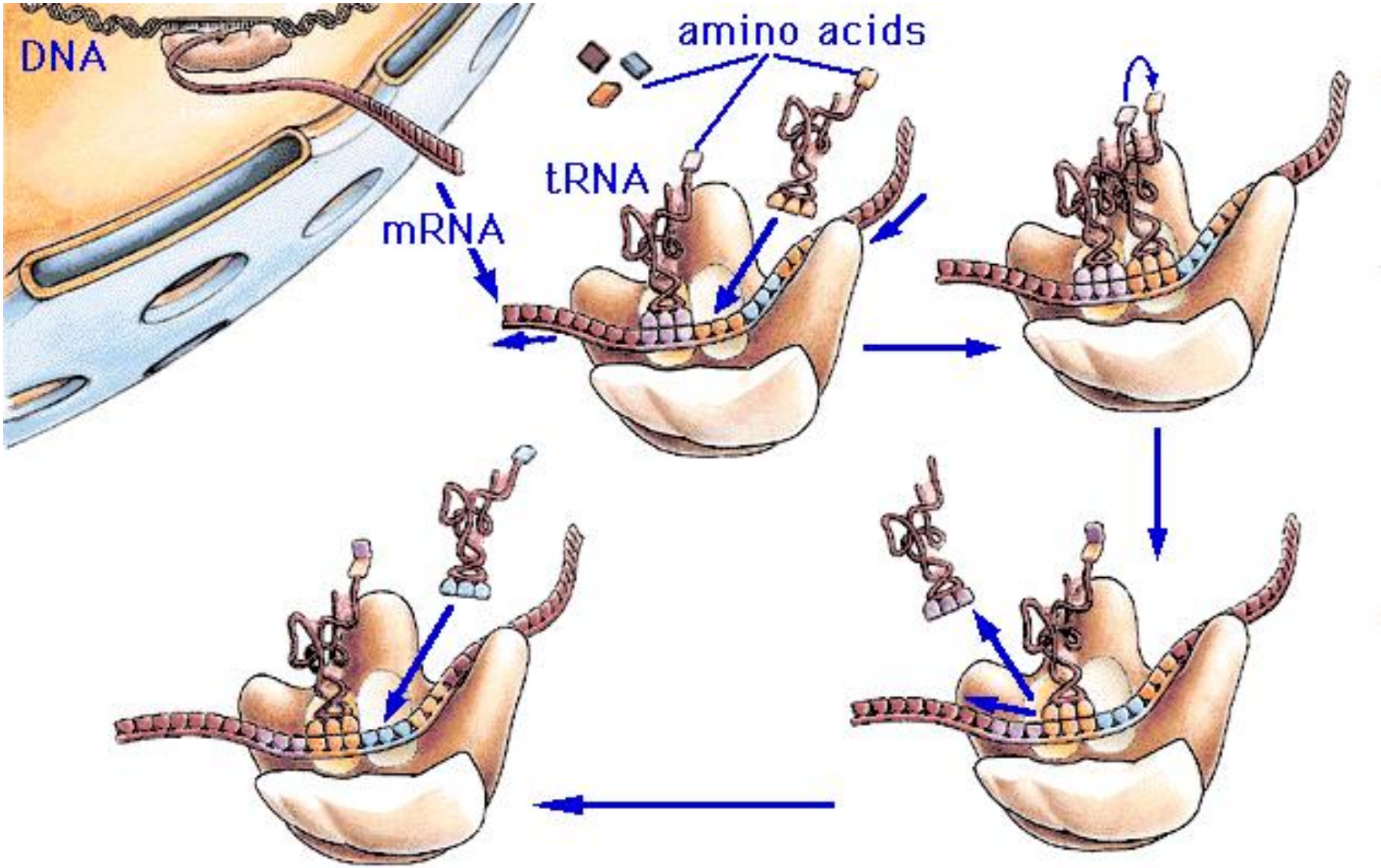
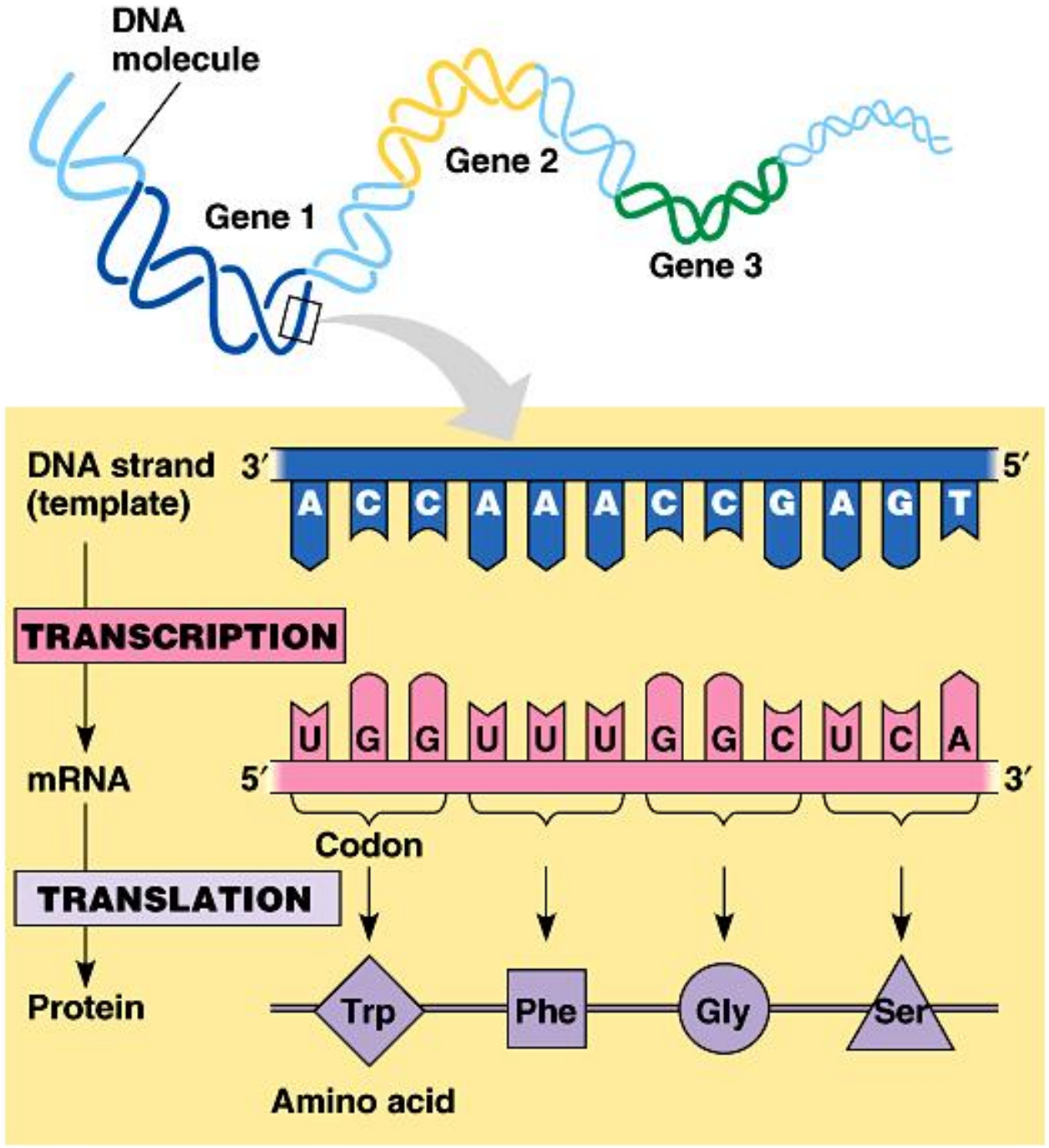
Translation





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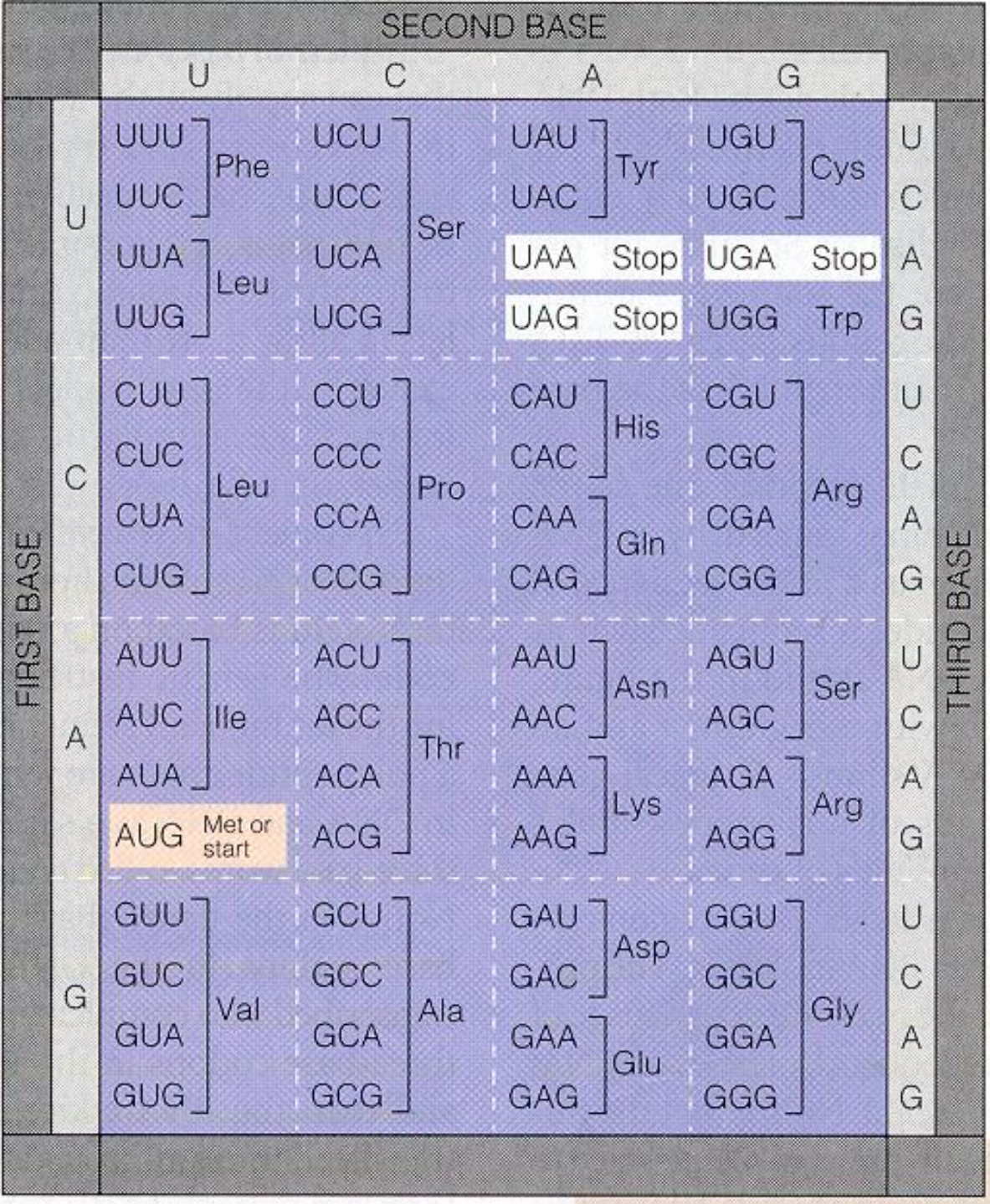
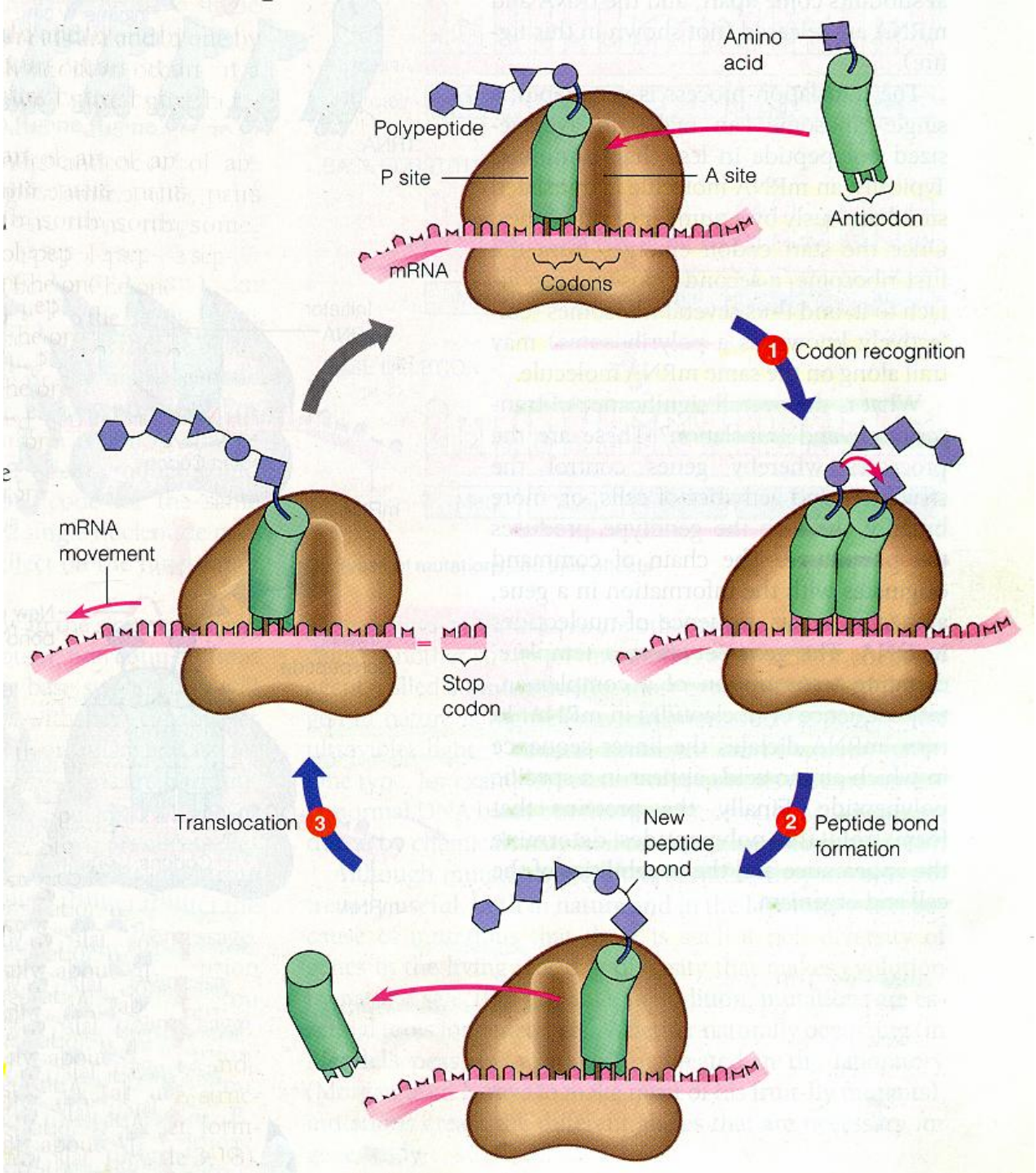
Genetic Code




Amino acid
Polypeptide
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A site
Anticodon
mRNA
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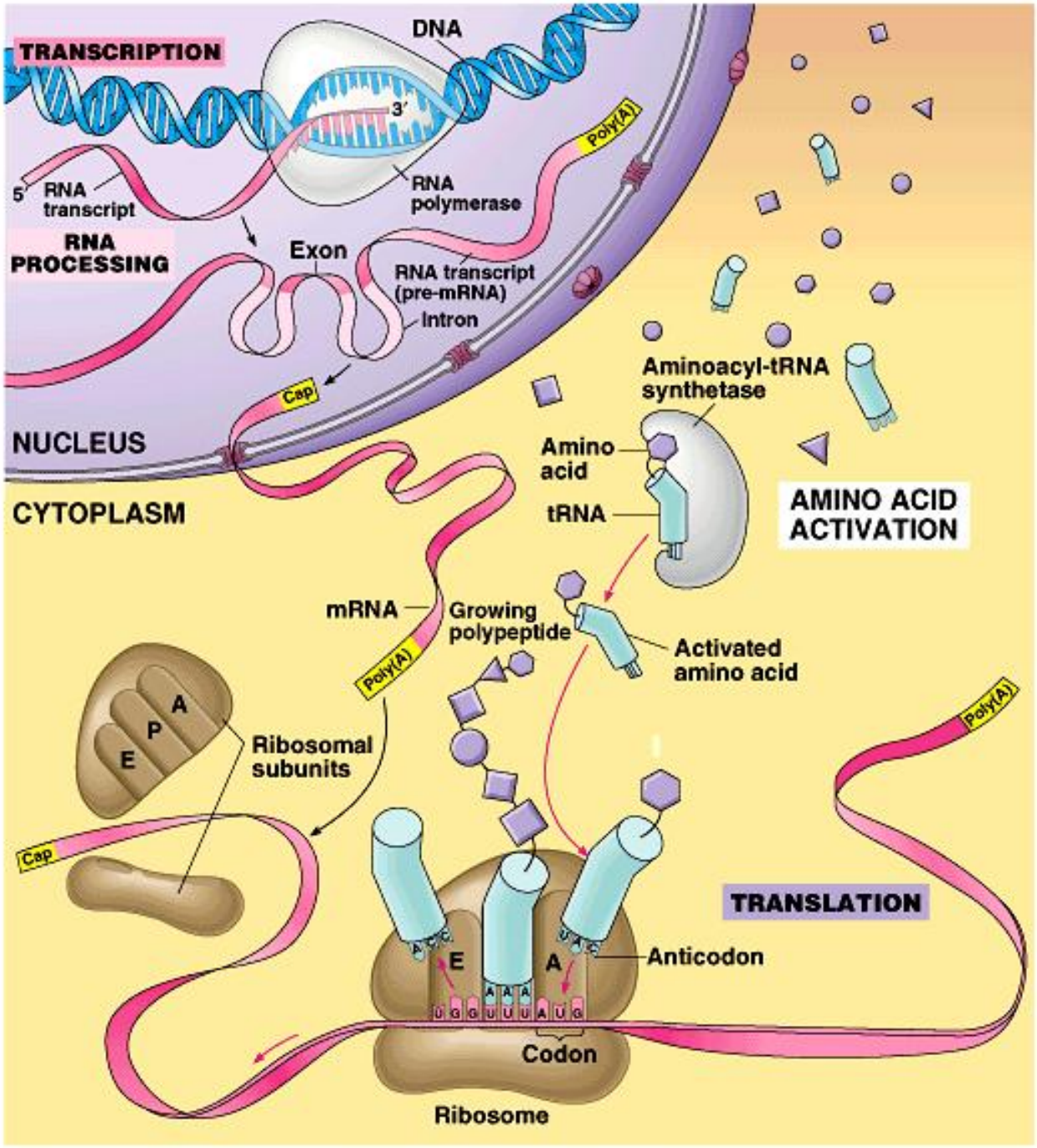
Stop codon
Translocation 3
New peptide bond
2 Peptide bond formation



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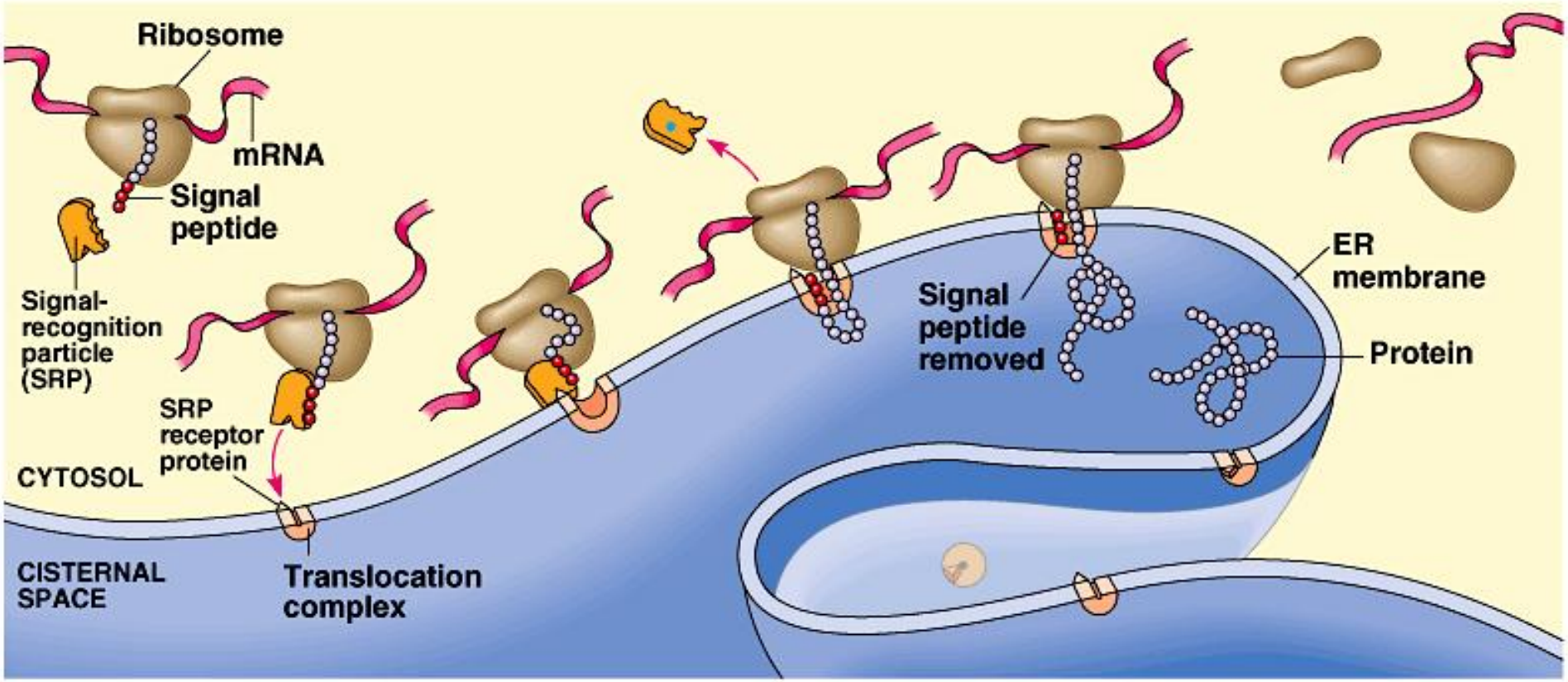

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- **Signal peptide-** determines the protein's destination
- **Posttranslational modification-** removing some amino acids segments, folding the protein and stabilizing it with disulfide bridges, adding carbohydrate moities, etc.